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DR. ROBERT B. OSGOOD

The people of the United States are under great obligation to that small northeastern corner of the country which is called New England. The men and institutions of New England have had an immeasurable influence on thought and progress in this land. In the field of medical education the contributions have been large. In the more recent past, continuing this New England tradition, Dr. Robert Bayley Osgood played no small part in the teaching of orthopedic surgery and in the training of young men for the practice of this branch of medicine.

Born in Salem, Mass., of sea-faring forebears, he decided as a youth to become a physician. After graduating from Amherst College in 1895, he entered the Harvard Medical School and received his doctorate in medicine in 1899. Good fortune led him to become a student house officer at the House of the Good Samaritan, where the treatment of the patients was largely orthopedic in nature. Here his skill and enthusiasm commended him to the visiting surgeons, particularly to Dr. Joel E. Goldthwait.

In 1899, after graduating from the Harvard Medical School and completing a surgical internship at the Massachusetts General Hospital, he became associated with Dr. Joel E. Goldthwait and Dr. Charles F. Painter in the relatively new specialty of orthopedic surgery. He became interested at this time in the recently discovered roentgen rays and, with Dr. Walter J. Dodd, studied their practical application to diseases of the bones and joints. He became assistant to the orthopedic clinic of the Carney Hospital and also to the Children's Hospital, in Boston. At the latter institution he served as roentgenologist until the pressure of his increasing practice forced him to relinquish this work.

When an orthopedic service was begun at the Massachusetts General Hospital, he resigned his other hospital appointments and became a visiting orthopedic surgeon at this clinic. Here, with his appointment as instructor in orthopedic surgery in the Harvard Medical School in 1913, came his first opportunity for teaching. During this period a large number of his contributions to medical literature were made. In 1903 he reported observations on a lesion of the epiphysis of the tibial tubercle, which has since come to bear his name. With Dr. Goldthwait he studied the pelvic articulations and demonstrated their relationship to disabilities of the low region of the back. Papers were published by him on such diverse subjects as foot strain (in connection with which he described an ingenious apparatus for measuring the strength of the supporting muscles of the feet), internal derangement of the knee joint, scoliosis, arthritis, the mobilization of stiffened joints and the transmission of the virus of poliomyelitis.

With the entry of the United States into World War I, Dr. Osgood volunteered for service. He was commissioned as major in the Medical Corps of the Army of the United States and was called into active service in May 1917. He played a notable role in the organization of orthopedic services for the care of wounded American soldiers in France, where he was for a time assigned to Base Hospital No. 5. Transferred to the Medical War Office in London, he assisted Sir Robert

Jones in the establishment of orthopedic hospitals in Great Britain. He was detailed to the headquarters of Medical and Surgical Consultants at Neufchateau, then to the Office of the Chief Surgeon of the A. E. F. at Tours. Later he served as orthopedic consultant to the Surgeon General's Office in Washington. His efforts here contributed greatly to improved splinting and transportation of the wounded. At the close of the war he was promoted to the rank of colonel in the Medical Reserve Corps.

On his return to civil life he was elected chief of the orthopedic service at the Massachusetts General Hospital in 1919. Here his unusual ability as organizer and head of a clinic were shown. The orthopedic service of the Massachusetts General Hospital under his leadership became an important center for both undergraduate and postgraduate teaching in orthopedic surgery. In 1922 he became professor of orthopedic surgery in the Harvard Medical School and chief of the orthopedic service of the Children's Hospital in Boston. In 1924 he was made John B. and Buckminster Brown professor of orthopedic surgery. It was in the period between 1922 and 1930 that he, with Dr. Nathaniel Allison, organized a postgraduate teaching service for orthopedic surgery in Boston which became internationally famous and which attracted students from all parts of North America.

In 1930 he resigned his professorship and became professor emeritus. Since giving up his teaching and hospital positions he has been no less active in striving to raise the standard of orthopedic practice and to improve medical care in general. As a member of the Physician's Committee on Medical Care he struggled against outmoded and unethical medical practices under a storm of official disapproval and saw the eventual adoption of a newer and fairer policy. As a member of the American Committee on Rheumatism he helped to organize and develop the American Rheumatism Association. His services have been often sought as a lecturer and his counsel welcomed on the boards of many civil and medical organizations. He is chairman of the Advisory Board of Orthopedic Surgeons to the Trustees of the Shriner's Hospitals for Crippled Children and a member of the Advisory Committee of the Services for Crippled Children of the Children's Bureau in Washington.

The eminent position which he has attained in medicine is attested by the many important honors which have come to him. He was president of the American Orthopedic Association in 1920-1921, president of the New England Surgical Society in 1928-1929 and president of the American Rheumatism Association in 1942-1943. Amherst College conferred on him the degree of Doctor of Science, honoris causa, in 1935. He has been elected an honorary member of the British, Italian, Scandinavian and Australian orthopedic associations and of the Royal Society of Medicine. He is a corresponding member of the Belgian Orthopaedic Association.

We who have been his pupils and associates remember him best as a great teacher. He is known in medical councils as an able executive and a wise counselor. In medical research his part has been chiefly that of giving helpful advice and encouragement, seeking no credit for himself. A man of sound scholarship, facile in voice and pen, of the highest ideals both for his personal life and his profession, generous to a fault, speaking evil of no man, he has wielded and continues to wield a great influence for good on the practice of orthopedic surgery in America.

J. G. K.

SURGICAL APPROACHES TO THE EPIPHYSIAL CARTILAGES OF THE KNEE AND ANKLE JOINTS

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Excision of an epiphysial cartilage for the arresting of growth is not a new surgical procedure. As early as 1873, such an operation was performed by Ollier [1] for the correction of deformities caused by unequal rates of growth in the bones of the forearm and the leg. He did not, however, advocate this procedure for the equalization of length of the leg.

In 1933, Phemister [2] published his paper on "Operative Arrestment of Longitudinal Growth of Bones in the Treatment of Deformities," in which he emphasized the value of this operation on the lower femoral and upper tibial epiphysial cartilages in treating unequal length of legs in growing children. Many surgeons, ourselves included, have adopted the method of Phemister because of its simplicity and because it is a generally applicable procedure for children during the period of growth. In performing the operation, however, we have not found the straight incisions used by Phemister entirely satisfactory for the purpose of adequate exposure of these epiphysial cartilages. With this in mind, we have carried out special dissections in the anatomic laboratories which have resulted in the development of surgical approaches giving adequate exposure. The purpose of this article is to describe and illustrate these approaches. In addition, a description of the surgical approaches to the epiphyses of the lower ends of the tibia and fibula have been included because they contribute a certain amount of growth to these two bones.

EXPOSURE OF THE LOWER FEMORAL AND UPPER TIBIAL EPIPHYSIAL CARTILAGES

The knee is held by sand bags in about 30 degrees of flexion, since this position relaxes the hamstring muscles and the bony landmarks can be readily palpated. If the lower femoral and the upper tibial epiphysis are to be fused at one operation, they are exposed through long, curved incisions over the internal and the external aspect of the knee joint. If either the lower femoral or the upper tibial epiphysis is to be fused alone, then the upper or lower halves respectively of the incisions are employed (fig. 1 *a* and 1 *b*).

Lateral Aspect of the Knee Joint.—The landmarks and important anatomic structures on the outer aspect of the joint are: (1) the lateral condyle of the femur; (2) the head of the fibula; (3) the tractus iliotibialis; (4) the lateral intermuscular septum; (5) the tendon of the biceps femoris muscle and (6) the common peroneal nerve.

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1. Ollier, L.: Traité des résections et des opérations conservatrices, qu'on peut pratiquer sur le système osseux, Paris, G. Masson, 1888, vol. 2, pp. 440-445; 1891, vol. 3, pp. 473-479.

2. Phemister, D. B.: Operative Arrestment of Longitudinal Growth of Bones in the Treatment of Deformities, J. Bone & Joint Surg. **15**:1-15, 1933.

In this region, the lateral condyle is the most prominent portion of the femur. It lies just above and in front of the head of the fibula. Over this prominence the tractus iliotibialis passes to its insertion into the upper margin of the lateral tuberosity of the tibia and into the head of the fibula. The tendon of the biceps muscle is also inserted into the head of the fibula. This insertion is bifurcated by the fibular collateral ligament, which joins the tip of the head of the fibula and the lateral condyle of the femur. Beneath this ligament lie the inferior lateral genicular vessels after passing beneath the plantaris muscle and the lateral head of the gastrocnemius. Between the tendon of the biceps muscle posteriorly and the tractus ilio-

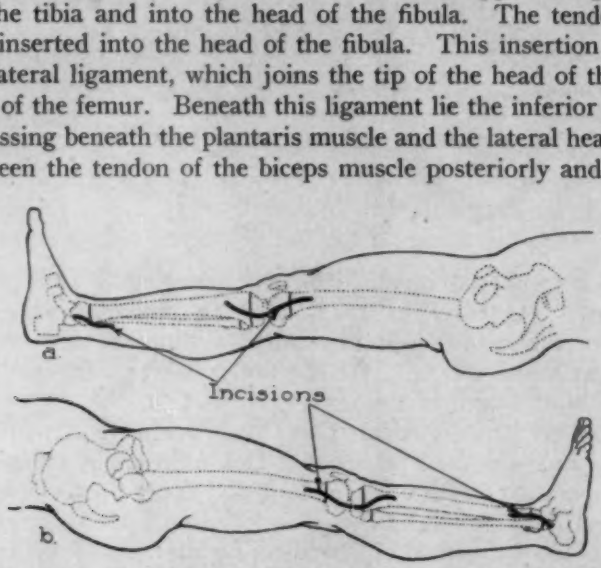

Fig. 1.—Sketches illustrating the lines of incision for the various approaches: *a*, the medial side of the leg; *b*, the lateral side of the leg.

Fig. 2.—Combined approach to the lateral aspect of the knee for fusion of the lower femoral and upper tibial and fibular cartilage plates at one operation.

tibialis anteriorly, a distinct interval can be felt, in which is located the lateral intermuscular septum. The common peroneal nerve passes distally and laterally along the medial side of the biceps tendon. Below, it follows the interval between the tendon of the biceps femoris muscle and the lateral head of the gastrocnemius. Finally, it turns anteriorly around the neck of the fibula under cover of the proximal part of the origin of the peroneus longus muscle.

The incision in the skin begins about 2½ inches (6.4 cm.) above the lateral condyle of the femur directly over the interval between the biceps tendon and the tractus iliotibialis. It curves downward and backward to the head of the fibula

and then gently forward on the lateral surface of the upper part of the tibia (fig. 1*b*). The lateral intermuscular septum is exposed in the upper part of the wound and traced to its attachment to the linea aspera; this frees some of the fibers of origin of the vastus lateralis from its anterior surface (fig. 2). The muscle is retracted forward to expose the lateral surface of the femur and its junction with the lateral condyle. This junction marks the site of the epiphysial cartilage (figs. 3 and 4). Immediately below, the capsule of the knee joint should be identified. The superior lateral genicular vessels appear directly on the bone, passing forward after piercing the septum, and are distributed to the fibers of the vastus lateralis. For good

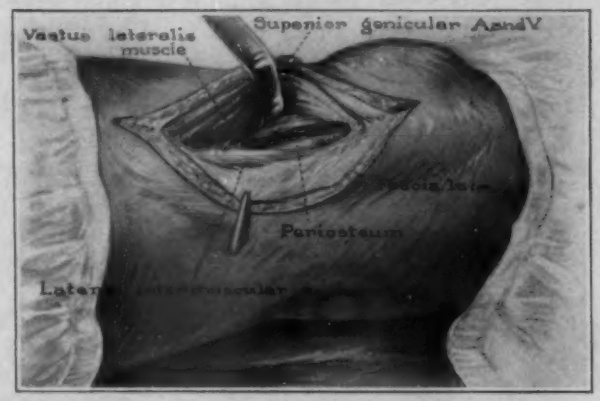

Fig. 3.—Detail of the approach to the lateral portion of the distal end of the femur.

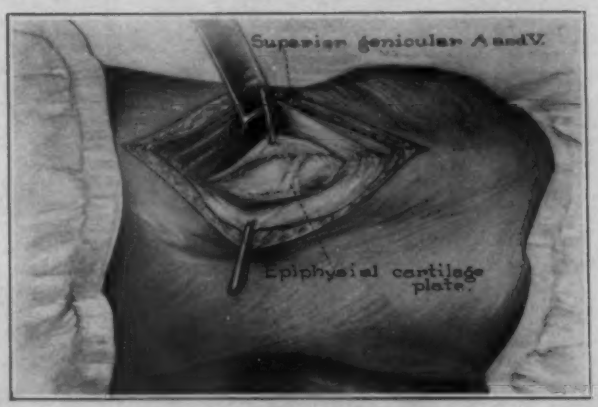

Fig. 4.—Detail of the approach to the cartilage plate at the lateral portion of the distal end of the femur after the periosteum has been elevated. The removal of a thin flake of bone by means of a sharp chisel will expose the cartilage plate.

exposure of the epiphysial line, they may require ligation. The periosteum is incised vertically, and a thin section of bone from the outer cortex is removed with an osteotome directly over the epiphysial line. The periosteum is then separated laterally, and a rectangular block of bone 2 cm. long and 1 cm. wide is removed, reversed and reinserted. Before this block of bone is replaced, however, the cartilage of the epiphysial line is removed with a curet to the depth of 1 cm. over as large a portion of the lateral circumference of the femur as can be reached. Subsequently, small shavings of bone are packed into the defect left in the cartilage plate, after which the rectangular block of bone is replaced (fig. 5).

The exposure of the upper fibular and tibial epiphysial cartilage is rendered safe by dissection of the common peroneal nerve. This structure is found by incision of the deep fascia directly posterior and internal to the tendon of the biceps muscle. From here it can be traced downward, freed at the neck of the fibula and retracted posteriorly (fig. 2). An incision over the upper and medial portions of the head of the fibula readily exposes its epiphysial cartilage; this is completely excised with an osteotome and the cavity then filled with thin shavings of bone. The cartilage plate of the tibia is revealed by downward reflection with a periosteal elevator of the upper fibers of origin of the extensor muscles from the arcuate line. The line of cartilage is shown by the removal of a thin section of bone ½ to ¾ inch (1.3 to 1.9 cm.) below the margin of the joint. It is fused by the rectangular block method previously described.

Medial Aspect of the Knee Joint.—The anatomic structures with which we are concerned on the inner aspect of the joint are: (1) the adductor tubercle of the femur; (2) the medial intermuscular septum; (3) the inner hamstring muscles.

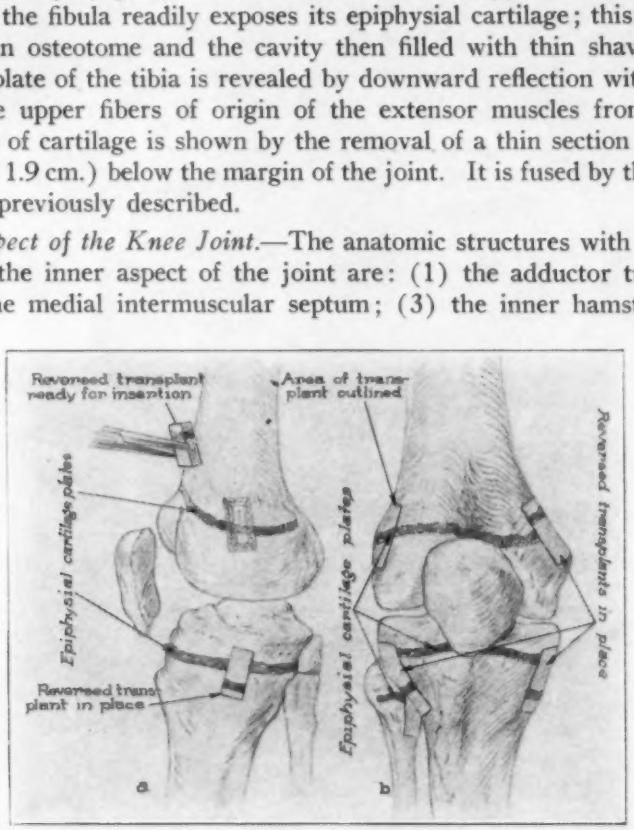

Fig. 5.—Diagram illustrating the details of the operative fusion of the epiphysial cartilages about the knee (drawn from Phemister [2]).

The adductor tubercle marks the junction of the epiphysis and diaphysis on the inner surface of the lower end of the femur. Into this prominent part of the bone the tendon of the adductor magnus muscle is inserted, and from it arises the superficial portion of the tibial collateral ligament. In addition, the joint capsule crosses the epiphysial cartilage at this level with the reflection of the synovial membrane just beneath it. Immediately proximal to the attachment of the joint capsule, the superior internal genicular vessels lie close to the bone, passing forward from the popliteal artery beneath the tendon of the adductor magnus.

The medial intermuscular septum is a much thinner membrane than the lateral intermuscular septum. It passes posteriorly from the general fascial envelope to its attachment with the linea aspera. This structure separates the adductor magnus muscle, behind, from the vastus medialis, in front, and it is in the interval between these two muscles that the epiphysial cartilage is readily exposed (fig. 6). The sartorius, gracilis and semitendinosus muscles pass over the tibial collateral ligament in the order named and from before backward to achieve insertion into

the upper, inner surface of the tibia. The infrapatellar branch of the saphenous nerve pierces the tendon of the sartorius muscle and turns forward to lie about ¾ inch (1.9 cm.) below the upper margin of the tibia. Here, this branch can be rolled beneath the fingers.

An incision 5 inches (13 cm.) in length is made with its center approximately at the level of the adductor tubercle. In its upper part it passes over the inner surface of the internal condyle of the femur, and in the lower part it curves gently forward to follow the anterior margin of the tendon of the sartorius (figs. 1 and 6). By incision of the deep fascia the anterior surface of the internal intermuscular septum is identified and traced to its attachment to the linea aspera. The vastus medialis, after separation of a few fibers of origin from the septum, is retracted anteriorly, exposing an interval the floor of which is the internal surface of the femur and its junction with the flare of the adductor tubercle (fig. 6). The anterior and the posterior wall of this space are formed respectively by the vastus medialis muscle and the tendinous portion of the adductor magnus. In the distal

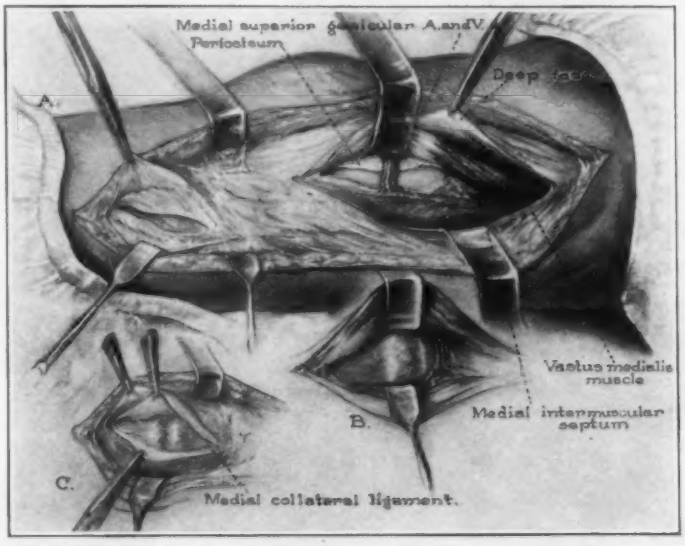

Fig. 6.—Combined approach to the medial aspect of the knee for fusion of the lower femoral and upper tibial cartilage plates at one operation.

portion of this space lies the epiphysial cartilage, overlapped by the attachment of the capsule and the reflected synovial membrane of the knee joint (fig. 6). The genicular vessels are ligated, and a vertical incision is made through the periosteum downward toward the epiphysial cartilage plate. The periosteum with the margin of joint capsule is pushed downward and laterally to expose the epiphysial cartilage. This exposure is facilitated by raising a portion of cortical bone. Fusion is carried out in the manner previously outlined.

The upper tibial epiphysis is now exposed by incising the deep fascia along the anterior margin of the sartorius tendon. The infrapatellar branch of the saphenous nerve lies forward and need not be exposed. In the depth of the wound the anterior margin of the tibial collateral ligament is found and retracted backward. The epiphysial cartilage is located directly in front of this ligament and ½ to ¾ inch (1.3 to 1.9 cm.) below the upper margin of the tibia. It is exposed and fused in the usual manner.

EXPOSURE OF THE EPIPHYSIAL CARTILAGES OF THE LOWER ENDS OF THE TIBIA AND FIBULA

For exposure of the epiphysial cartilages of the lower end of the fibula and the lateral aspects of the lower end of the tibia, an outward incision is made at the tip of the fibula and extended upward along the anterior margin of this bone for a distance of 2½ inches (6.4 cm.) (fig. 1 *b*). The anterior ligament of the

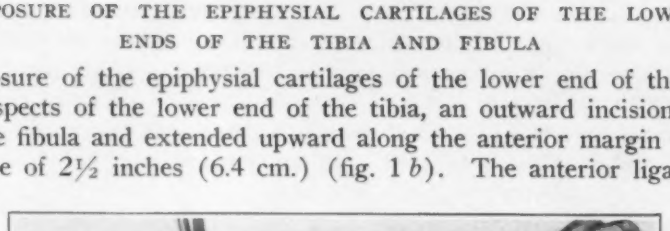

Fig. 7.—The approach to the lateral portion of the epiphysial cartilage of the lower end of the tibia and the epiphysial cartilage of the lower end of the fibula.

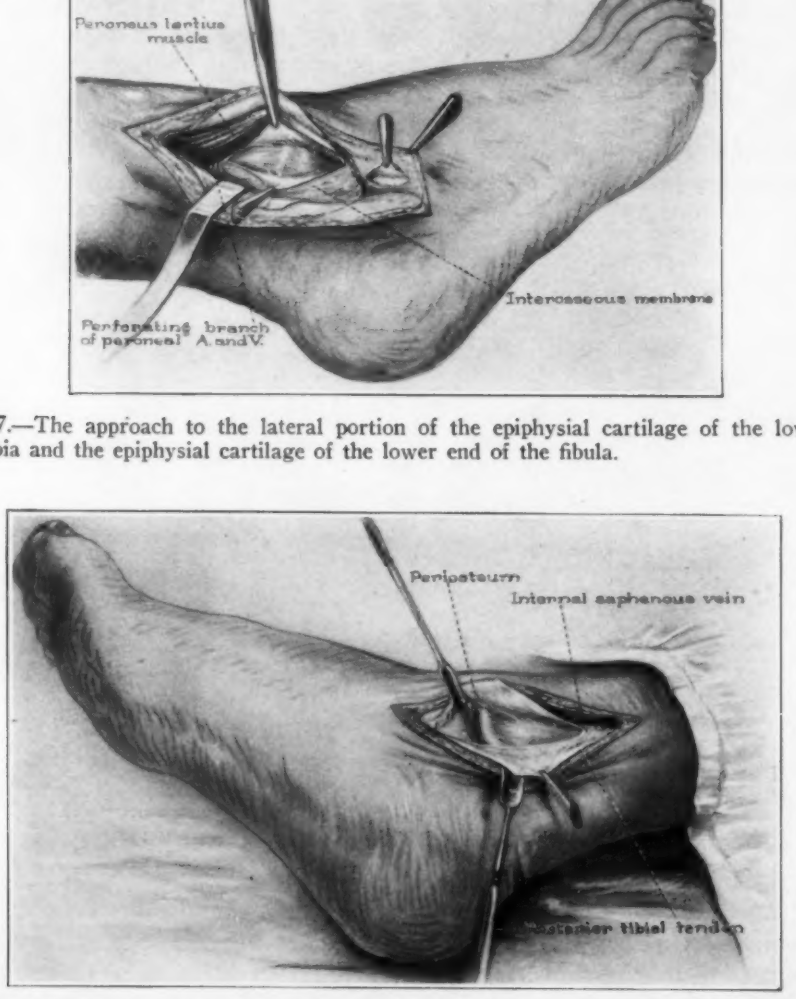

Fig. 8.—The approach to the medial aspect of the epiphysial cartilage of the lower end of the tibia.

lateral malleolus is identified and the deep fascia incised upward for about 1½ inches (3.9 cm.) above its upper margin. The peroneus tertius muscle is then retracted forward from its origin in the lower part of the fibula and the adjacent portion of the interosseous membrane (fig. 7). The perforating branches of the peroneal artery are seen lying on the interosseous membrane and may be either retracted or ligated as conditions warrant. From just above the attachment of the joint capsule, a vertical incision is made over the epiphysial cartilage of the

tibia, which in this location is about ½ inch (1.3 cm.) above the margin of the ankle joint. The periosteum is reflected laterally while the epiphysial cartilage is exposed and fused. About ½ inch above the tip of the fibula, the epiphysial cartilage of this bone is exposed and completely excised. The defect is then filled with bone chips.

On the medial aspect of the tibia, the skin incision, about 2 inches (5 cm.) in length, is made along the posterior margin of the tibia and internal malleolus (fig. 1). The saphenous vein lies anteriorly to this incision, while the flattened tendon of the tibialis posticus muscle forms a groove on the posterior part of the medial malleolus (fig. 8). The epiphysial cartilage lies about ¾ to 1 inch (1.9 to 2.5 cm.) above the tip of the medial malleolus. It is brought into view by the elevation of the periosteum and the removal of a thin layer of bone. Care should be taken to curet the epiphysial cartilage well down over the posterior aspect of the tibia.

All of the wounds are closed by approximation of the deep fascia and the skin with interrupted silk sutures. Dressings are applied, and immobilization by splints or plaster is not necessary.

CONCLUSIONS

Surgical approaches to the epiphysial cartilages of the lower end of the femur and the upper and lower ends of the tibia and fibula are described in this paper. We have found that these approaches give adequate exposure for fusion of the cartilages and also permit due regard for the preservation of anatomic structures.

Dr. John Saunders, Professor of Anatomy, University of California, provided the facilities for the anatomic dissections.

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DISLOCATION OF THE KNEE

REPORT OF FOUR CASES

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Complete dislocation of the knee is relatively rare. Robbins [1] stated that up to 1909 only 270 cases had been reported in the literature, of which 114 were of the forward or anterior type of complete dislocation. Ritter [2] reported that complete dislocation of the knee was observed in only 1 of 23,000 patients admitted to the Reconstruction Hospital in New York. Ransohoff [3] stated that at the Cincinnati General Hospital only 3 persons with complete dislocation of the knee had been encountered in a period of twenty-eight years—1 had posterior and lateral dislocation, 1 anterior and lateral dislocation and 1 incomplete lateral dislocation.

As is well known, there are five types of dislocation: (*a*) anterior, (*b*) posterior, (*c*) medial, (*d*) lateral and (*e*) rotary. These are named according to the ways in which the tibia is displaced on the femur.

There is always considerable tearing of the lateral and cruciate ligaments in dislocation of the knee. The more complete the dislocation, the more complete is the tear.

COMPLICATIONS

The popliteal vessels are torn occasionally, resulting in gangrene and loss of the leg. A case has been reported by me [4] in which there was a rupture of the popliteal artery and vein, resulting in gangrene. Robbins quoted Herring's experience of 6 miners who were caught in a shaft; 3 had forward dislocation, and in 2 cases amputation was necessary because of gangrene following injury of the popliteal vessels. He also quoted Hardouin, who found that in a series of 27 cases of posterior dislocation it was necessary to do 12 amputations because of injury to blood vessels. Ferguson and Allen [4a] reported a case in which thrombosis of the posterior tibial artery necessitated amputation of the leg thirty-five days after the initial injury.

Case 4 in the present series of 4 cases is another example of injury to the vessels following dislocation.

Neural complications have been reported by several authors. Mitchell [5] reported a case of anterior dislocation with peroneal paralysis, in which recovery was not complete. In a case of thrombosis of the posterior tibial vessel reported by Ferguson and Allen a complete division of the common peroneal nerve was shown. Patter-

1. Robbins, F. R.: Forward Dislocation of the Knee, Ann. Surg. **95**:306 (Feb.) 1932.

2. Ritter, H. H.: Dislocation of the Knee Joint, with Report of a Case, J. Bone & Joint Surg. **14**:391-394 (April) 1932.

3. Ransohoff, J.: Dislocations of the Knee, Tr. West. S. A., December 1915, p. 81.

4. Anderson, R. L.: Dislocation of the Knee with Rupture of the Popliteal Artery and Vein: Report of Case, Virginia M. Monthly **58**:120-123 (May) 1931.

4a. Ferguson, J. A., and Allen, L.: Complete Medial Dislocation of the Knee Joint with Division of the Common Peroneal Nerve, J. Bone & Joint Surg. **21**:1012-1014 (Oct.) 1939.

5. Mitchell, J. I.: Dislocation of the Knee: Report of Four Cases, J. Bone & Joint Surg. **12**:640-646 (July) 1930.

son [6] reported a case in which there was mild residual foot drop following dislocation of the knee.

Case 1 in the present series illustrates another complication, i. e., the necessity of open reduction, which may occur infrequently. Ruppanner [7] quoted Pagenstecher's review of 8 cases in the literature in which an operation was necessary for reduction. Ruppanner also reported a case in which a tibia in incomplete posterior and lateral dislocation was replaced by open reduction.

A frequent complication is one or more concomitant fractures, such as a fracture of the tibial spine or of the head of the fibula, and these usually require no special treatment.

The treatment consists of gentle reduction, usually by traction and pressure and counterpressure on the tibia and the femur with the patient under general anesthesia. It is agreed by all that after reduction a plaster cylinder should be used. There is some disagreement as to the length of time during which the complete plaster cylinder should be used. There is no general agreement as to how long the knee should be protected otherwise. Key and Conwell [8a] and also Conwell and Alldredge [8b] have advocated the use of a plaster cast for at least eight to twelve weeks. This is followed, if necessary, by a knee cage. Ritter reported a case, however, in which the cast was worn for only ten days, and then a walking caliper was applied, which was worn for five months with a good result. Longeway and Richardson [9] reported a case in which the cast was removed after fifteen days and a posterior splint applied, and later a hinged splint. Huber, Yaffe and Podlasky [10] and Wilson, Michele and Jacobson [11] cited cases in which there was a shorter time of immobilization with good results. Weigel [12] reported a case of anterior dislocation in which the knee was immobilized for five weeks. After two weeks the cast was bivalved for baking and massage. The patient began to bear weight after six weeks, and after eight weeks he was walking without crutches or cane. There was complete stability after three months. Weigel expressed the opinion that the result was due to good muscular development with exercises. Platt,[13] on the other hand, reported a case in which the cast was worn for four months.

Most authors feel that conservative treatment should be used first. Wilson, Michele and Jacobson stated that no operative treatment for the repair of ligaments should be used for at least two years. On the other hand, Hey Groves [14] recommended operative treatment for repair of the ligaments. There is no question about the tearing of the ligaments. The only question involved is whether or not the ligaments will heal sufficiently with protective treatment to function adequately.

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6. Patterson, R. H.: Anterior Dislocation of the Knee Joint, Ann. Surg. **99**:521 (March) 1934.

7. Ruppanner, E.: Zur Kenntnis der irreponiblen Kniegelenksluxationen, Deutsche Ztschr. f. Chir. **83**:554, 1906.

8. (*a*) Key, J. A., and Conwell H. E.: Fractures, Dislocations and Sprains, ed. 2, St. Louis, C. V. Mosby Company, 1937, p. 1024. (*b*) Conwell, H. E., and Alldredge, R. H.: Complete Dislocations of the Knee Joint: A Report of Seven Cases with End-Results, Surg., Gynec. & Obst. **64**:94-101 (Jan.) 1937.

9. Longeway, A. F., and Richardson, R. B.: Report of a Case of Complete Traumatic Dislocation of the Knee Joint Without Compounding, Journal-Lancet **51**:120-122 (Feb.) 1931.

10. Huber, H. H.; Yaffe, A., and Podlasky, H. B.: Traumatic Dislocation of the Knee Joint: Report of a Case, Radiology **7**:431-435 (Nov.) 1926.

11. Wilson, M. J.; Michele, A. A., and Jacobson, E. W.: Complete Dislocation of the Knee Joint, Am. J. Surg. **52**:77-81 (April) 1941.

12. Weigel, E. W.: Complete Dislocation of Knee, Am. J. Surg. **9**:140-141 (July) 1930.

13. Platt, H.: Traumatic Dislocation of the Knee Joint, Brit. J. Surg. **8**:190-192 (Oct.) 1920.

14. Hey Groves, cited by Huber, Yaffe and Podlasky.[10]

REPORT OF CASES

CASE 1.—A white man 52 years of age sustained an injury to his right knee on Jan. 7, 1942 when he was struck on a railroad trestle and knocked to the ground about 30 feet (9 meters) below. He was brought immediately to the McMillan Hospital in Charleston, where he complained chiefly of pain in the right knee.

Examination revealed that the tibia was displaced laterally on the femur (fig. 1 *A*). On the medial aspect of the knee over the medial condyle of the femur the skin was drawn taut and was at first cyanotic and later blanched. Just below this point there was a distinct dimple in the skin, corresponding to the line of the joint. Roentgen examination showed incomplete

Fig. 1 (case 1).—*A*, roentgen films taken before reduction of incomplete lateral dislocation of the tibia on the right femur. *B*, after reduction.

lateral dislocation of the knee. With the patient under general anesthesia, an effort was made to reduce this deformity by manipulation both by my associate and by me, but it was unsuccessful.

We believed that this deformity had to be reduced promptly, as the circulation of the skin over the medial condyle of the tibia was poor.

Open reduction was performed. A 2½ inch (6.5 cm.) incision was made longitudinally over the median side of the knee. A small incision was made in the capsule of the joint, and a portion of the capsule on the medial side was found tucked under the femoral condyle. This was released with little difficulty by means of a Kelly clamp, and reduction was immediate and complete. This was confirmed by subsequent roentgen examination. The capsule and the skin were resutured, and a plaster cast was applied.

Convalescence was uneventful, and on the twenty-first day after his admission to the hospital the patient left, wearing a plaster cast. Two months later the cast was bivalved, and exercises were begun for the quadriceps muscle group, the anterior portion of the cast being removed. Two and one-half months afterward a hinged cast was applied.

Four months after the injury he still had considerable relaxation of the internal lateral ligament. A new hinged cast was applied. Subsequent examinations have shown gradual decrease in this relaxation, and the patient now walks without any support, showing slight relaxation in the internal lateral ligament and good motion in flexion.

CASE 2.—A Negro woman 55 years of age slipped and fell on Sept. 3, 1941, twisting her knee, while passing from one room to another in her work as a maid. When she was first seen, this woman of 250 pounds (113.5 Kg.) was lying in a corner near the door. She was placed on a stretcher with difficulty and taken immediately to the Charleston General Hospital.

Examination showed the right tibia to be displaced anteriorly and medially. There was marked swelling of the knee. The circulation and the nerves were intact.

Roentgen examination showed complete anterior and incomplete medial dislocation of the right knee. There was also a fracture of the head of the right fibula.

With the patient under general anesthesia, the dislocation was reduced by manipulation without difficulty. The postreduction roentgen film showed complete reduction.

The ligamentous relaxation was extreme, and the plastic cylinder was applied with unusual care to prevent redislocation.

She left the hospital on the following day. The circulation was good. She remained in bed for two weeks and then began to move about on crutches.

Eight weeks later there was marked evidence of relaxation of the internal lateral ligament, and there was still some relaxation of the anterior and posterior ligaments. Eight weeks after the injury the cast was bivalved, and measurements were taken for a long leg brace. One week later the brace was fitted, and motion was begun in the knee. Three months after the injury she began to bear weight. Six months after the injury she still had some relaxation of both lateral ligaments, especially the external lateral ligament, and some relaxation of both cruciate ligaments. However, this was decreasing steadily. Flexion of the knee was only slightly impaired at this time. It was believed that she was gaining a satisfactory result, although it will probably take another six months, with protection of the knee by a brace, for her to have a stable knee.

CASE 3.—A white woman 32 years of age was struck by an automobile on April 26, 1942, and the wheel of the automobile was said to have run over her left knee. She complained of pain in this knee. Examination on entrance showed complete anterior dislocation of the tibia on the femur. Unfortunately, a roentgen film was not taken before manipulation. Reduction was very easy by traction and manipulation. The roentgen film taken after reduction showed a fracture of the tibial spine and one of the head of the fibula in addition to the anterior dislocation. There was considerable swelling, and a metal splint was applied, which was changed to a plaster cast after four days. She left the hospital six days after the injury.

Six weeks and five days after the accident a hinged cast was applied, and motion of the knee was begun with bearing of weight. This cast was not comfortable, and three weeks later a brace was applied.

A little over five months after the accident she started leaving off the brace from time to time. Six months after the injury she was leaving off the brace more and more. At that time examination showed only slight relaxation of the anterior cruciate ligament, none in the posterior cruciate ligament, none in the internal lateral ligament and slight relaxation of the external lateral ligament. Flexion was present to 100 degrees. The musculature was in good condition, especially the quadriceps group.

She is still improving steadily, and an excellent result is anticipated. She does all of her own housework at this time and has no discomfort of the knee.

CASE 4.—A white man 76 years of age was injured at noon on June 17, 1942 when a horse kicked him and trampled on him. He was in the country and was not seen by us at the Kanawha Valley Hospital until three hours later. He was then in moderate shock. The left knee showed typical complete anterior dislocation of the tibia. The whole left lower leg was cold, and neither the pulse of the posterior tibial nor that of the dorsalis pedis artery was palpable. The roentgen films showed complete anterior dislocation of the tibia with a fracture of the head of the fibula and also marked calcification of the blood vessels. Unfortunately, these roentgen films have been misplaced.

General anesthesia was induced, and reduction was easy. A posterior splint was applied.

We were never able to palpate any pulse in the left foot, and the circulation remained greatly impaired. The whole leg became gangrenous up to the knee, and eleven days later, on

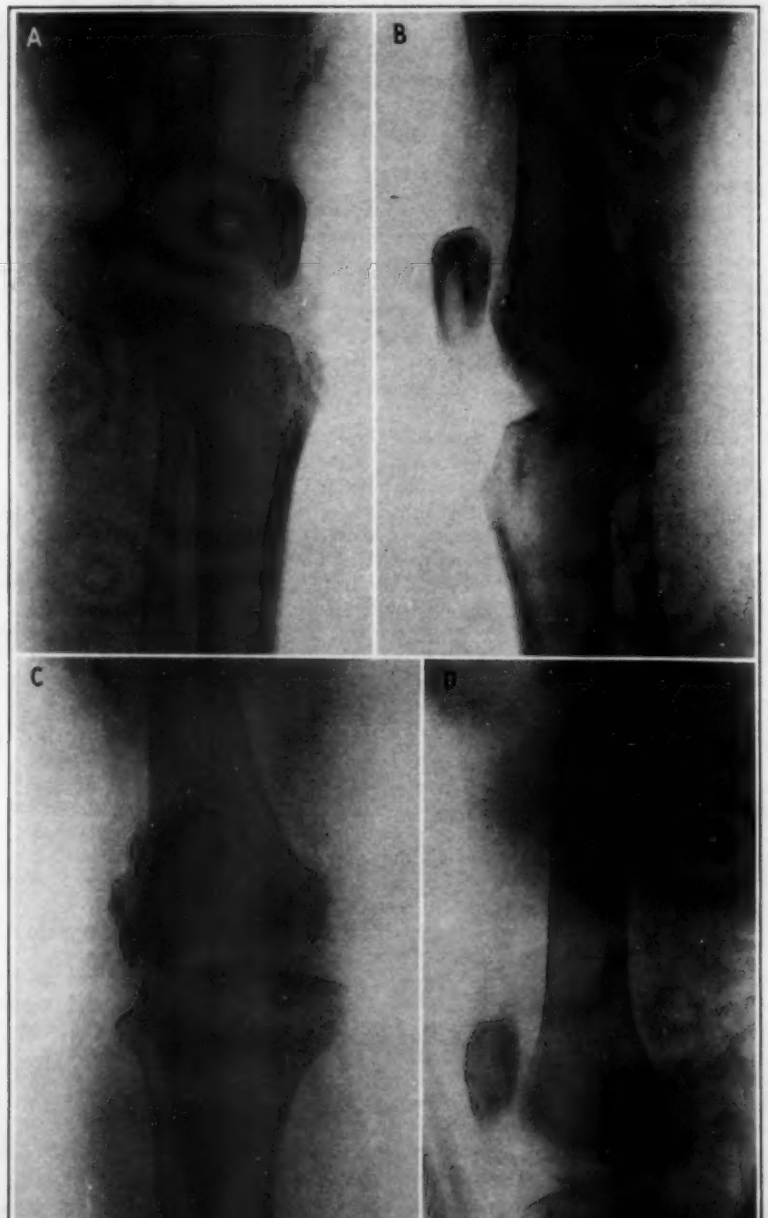

Fig. 2 (case 2).—*A*, lateral roentgen film taken before reduction of complete anterior and incomplete medial dislocation of the tibia on the right femur; *B*, after reduction. *C*, anteroposterior roentgen film taken before reduction; *D*, after reduction.

June 28, a guillotine amputation was performed in the lower part of the thigh. Traction was then applied after the usual method. The pathologic report was as follows:

"The dissection was performed twenty-four hours after amputation. The left leg was amputated about 10 cm. above the knee. All the toes and the anterior half of the foot showed blackish discoloration and were dry. The skin of the dorsum pedis was bluish. The subcutaneous tissue in the area on incision drained a large amount of brownish foul-smelling fluid. The skin of the lower part of the foot showed in some areas similar changes, especially on the lateral side. The margins of the amputation wound were irregular. On dissection the subcutaneous tissue of the whole leg showed blackish red discoloration. After dissection of the muscles the nerves and the blood vessels seemed to be embedded in blackish hemorrhagic tissue. Serial sections through the large blood vessels, including the popliteal artery and vein, showed extensive thrombosis completely obliterating the lumens of both arteries and veins. In the popliteal artery the thrombus showed a light brown color. There was an oblique fracture of the capitulum of the fibula.

"Sections from many areas of the popliteal and posterior tibial arteries were examined. The popliteal artery showed marked thickening of its intima and cholesterol deposits. In some areas the atheromatous content was emptied into the lumen and was visible within the thrombus. The

Fig. 3 (case 3).—Roentgen film taken after reduction of complete anterior dislocation of the tibia on the left femur, showing a fracture of the tibial spine and one of the head of the fibula.

media, beginning from the distal end of the popliteal artery downward, showed very extensive calcification. The lumens of all arteries and veins were occluded by thrombi.

"Diagnosis: Dislocation of the left knee; partly dry, partly moist gangrene of the foot and of the distal third of the lower leg; extensive thrombosis of all arteries and veins; extensive arteriosclerosis, mostly of the Mönckeberg type."

Immediately after the operation the patient began to improve, and with the aid of transfusions, made satisfactory progress. He left the hospital on July 22, 1942.

The stump granulated slowly and finally healed in four months. The poor general circulation undoubtedly contributed materially to this delay.

SUMMARY

Four cases are reported: (1) incomplete lateral dislocation for which open reduction was necessary; (2) complete anterior and incomplete medial dislocation; (3) complete anterior dislocation; (4) complete anterior dislocation followed by thrombosis of the popliteal vessels and gangrene.

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KNOWING HOW TO LIVE

RODNEY F. ATSATT, M.D.
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To honor Dr. Robert Bayley Osgood is instinctive in all who know him, and to contribute to this volume is a privilege, for what orthopedic surgeon does not owe an everlasting debt of gratitude to this teacher and friend?

The title of this brief essay has been chosen with care, for "Dr. Bobby," as he is affectionately known to most of his students, is indeed an expert at the fine art of living.

As a young man, Dr. Osgood worked hard. He was a leading surgeon in World War I, and he labored unceasingly to build and perfect the orthopedic services at the Massachusetts General Hospital and the Children's Hospital. But fifteen years ago he began to exhibit a faculty often seen in men who are wise as well as great—the faculty of relaxation.

Relaxation is a gift, or rather an art, for while its roots are in the personality, perhaps in the endocrine apparatus, only with practice and studious application does one attain the ability to lock up the troubles of the day within an exit-proof compartment of the mind, and thus at the appointed time turn one's attention to some of the finer things of life.

Dr. Osgood has always been a man to whom family life has had a strong appeal. I still treasure our memories of his Sunday "open house," to which house officers of the Massachusetts General Hospital were frequently invited. The simple dignity of his home reflected a quality which is found in few men of this generation.

Relaxation in some persons might be taken for indolence, but there is never such a thought in reference to Dr. Osgood. His keenness of mind, his ability to make rapid decisions and his kindly but effective word of command leave no doubt as to his mental and physical activity. His interest in old books, so well shown in his splendid exhibit at the 1940 American academy of Orthopedic Surgeons, his appreciation of art and music—all these things have contributed to keep him young in spirit and healthy in body, and to make him really great.

Success cannot be measured by how much money a man makes, how fine a car he drives or how high his name appears in the social register, even though such things may seem important in these competitive days. But the man who enjoys life, who wears well, who really lives in the broader sense, is the one who takes time for his hobbies, his recreation and above all for definite relaxation. The average man says, "But I haven't time." That man is an egoist, for important as he may seem to be, no one can drop out of the mad race without finding his place filled by some one fully competent to carry on.

And this I should like to say to you, Dr. Osgood, in all seriousness: You have always been an outstanding figure in your chosen field of Orthopedic Surgery. But more than that, you have guided many minds and hands into the right pathways. Thus you have inspired and enlightened your successors. Thus the men you have molded will carry on the ideals, the power and the spirit which are so essentially yours. But the greatest contribution you have made to us all is the example of your blessed serenity in the midst of a tremendously full life.

MUSCLE TRANSPLANTATION FOR COMBINED FLEXION–INTERNAL ROTATION DEFORMITY OF THE THIGH IN SPASTIC PARALYSIS

COMMANDER JOSEPH S. BARR (MC), U.S.N.R.

Cases of cerebral spastic birth palsy not infrequently present the problem of the management of a flexion-internal rotation deformity of the thigh. In spite of prolonged training of muscles, it may be necessary to resort to operative procedures to improve muscle balance and relieve the deformity. In this paper I shall describe an operation used by me for the past ten years for the relief of this type of deformity. In this operation the muscles causing the deformity are transposed from their site of origin and attached to a new site on the ilium. In the new position they act as abductors, external rotators and extensors of the thigh.

MUSCLES INVOLVED IN SPASTIC DEFORMITY OF THE THIGH

The cerebral lesion of spastic birth palsy is usually sufficiently diffuse to impair the function of groups of muscles. A single deformity is not as common as is a compound one in which several or all of the muscles about the hip are involved. The deformity of flexion–adduction–internal rotation is common. The predominant element may be adduction, it may be flexion, or it may be internal rotation.

If the predominant spasticity is that of the adductor group of muscles, satisfactory relief may be secured by adductor tenotomy and obturator neurectomy. This spastic deformity of the thigh is indeed the most common and this operative procedure the most satisfactory for its relief. It should be remembered, when adductor tenotomy is proposed, that the adductor magnus muscle is one of the prime extensors of the hip.[1] Therefore, if its tendon is severed, the power of active extension of the hip may be seriously impaired.

Internal rotation unaccompanied by other motion of the hip is produced by contraction of the anterior portions of the gluteus medius and minimus muscles. In the combined movements of internal rotation and hip flexion the tensor fasciae latae muscle also is called into action. Clinical observation of cases of cerebral spastic birth palsy in which there is the combined deformity of flexion and internal rotation leads to the conclusion that spasm of the tensor fasciae latae muscle is often a dominant factor.

Of the various operations for the relief of internal rotation deformity, the one devised by Durham [2] seems to yield the best results of any yet described. It consists of tenotomy of a portion of the gluteus medius and minimus muscles at their insertion into the great trochanter and division of the fascia lata at the same level.

Following the general observation that the antagonists of spastic muscles are weaker than normal, the extensors, abductors and external rotators of the thigh are usually impaired in power when there is spastic flexion–adduction–internal rotation contracture. One of the dangers in tenotomy of the gluteus medius and minimus tendons for the relief of internal rotation deformity (as pointed out by Durham) is that abductor power may be weakened. The operation described in this paper has the effect of reenforcing the power of abduction, external rotation and extension and at the same time diminishing the power of flexion and internal rotation. There-

1. Wright, W.: Muscle Function, New York, Paul B. Hoeber, 1928.
2. Durham, H. A.: A Procedure for the Correction of Internal Rotation of the Thigh in Spastic Paralysis, J. Bone & Joint Surg. **20**:339 (April) 1938.

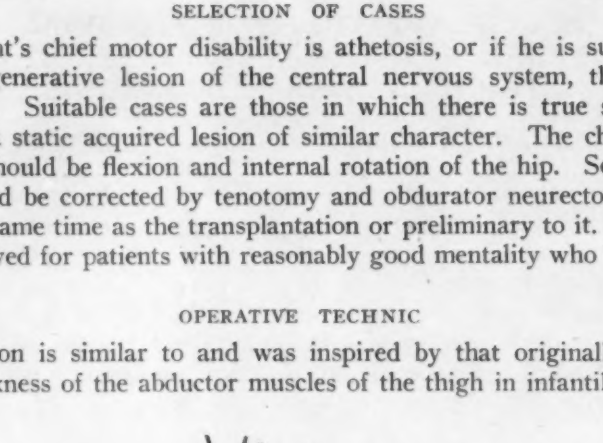
fore, on theoretic grounds it would appear to be superior to simple tenotomy of the overactive muscles.

SELECTION OF CASES

If the patient's chief motor disability is athetosis, or if he is suffering from a progressive degenerative lesion of the central nervous system, the operation is contraindicated. Suitable cases are those in which there is true spastic cerebral birth palsy or a static acquired lesion of similar character. The chief elements in the deformity should be flexion and internal rotation of the hip. Severe adduction deformity should be corrected by tenotomy and obdurator neurectomy. This may be done at the same time as the transplantation or preliminary to it. The operation should be reserved for patients with reasonably good mentality who have the ability to walk.

OPERATIVE TECHNIC

The operation is similar to and was inspired by that originally described by Legg [3] for weakness of the abductor muscles of the thigh in infantile paralysis, but



Operative sketch showing the approximate amount of muscle transposed and the method of securing the free end of the muscle to the ilium.

differs from it in several essential features. It consists in freeing the tensor fasciae latae, together with the anterior third of the gluteus medius and minimus muscles, from their iliac origins and reattaching them to the ilium at a point slightly posterior to the great trochanter (fig.).

1. With the patient under general or spinal anesthesia and lying on the side opposite that of operation or in a hip trough,[4] a generous field is prepared. This should extend from the lower ribs to the knee, including the whole thigh, and from the midline of the abdomen anteriorly to the midline of the back. The leg is draped separately, so that it can be manipulated during the operation. Severe adductor spasm must be overcome by adductor tenotomy and/or obturator neurectomy before proceeding with the operation.

3. Legg, A. T.: Tensor Fascia Femoris Transplantation in Cases of Weakened Gluteus Medius, New England J. Med. **209**:61 (July 13) 1933.

4. Gill, A. B.: Personal communication to the author.

2. The operative incision begins at the posterior superior spine of the ilium and curves forward along the iliac crest to the anterior superior spine. From that point it is extended downward and slightly outward on the anterior part of the thigh for about 6 to 8 inches (15 to 20 Cm.). After the incision is carried down to the deep fascia, the cutaneous flap is reflected from the underlying tensor fasciae latae muscle.

3. The anterior edge of the tensor fasciae latae muscle is freed distally to the point at which the ascending branch of the anterior femoral circumflex artery comes into view. Beginning inferiorly at the anterior edge of the muscle, the operator frees its under surface, carrying the dissection from below upward. Freeing the posterior margin of the muscle is unnecessary, and, if attempted, there is danger of damaging its nerve and blood supply. As the dissection is carried above the great trochanter, the anterior border of the gluteus minimus muscle is defined. A muscle mass consisting of the whole of the tensor fasciae latae muscle and the anterior third of the gluteus minimus and gluteus medius muscles is freed from its iliac origin (fig.). Two or three traction sutures are secured to the free end of the muscle mass.

4. The new site for attachment of the muscle is selected in the following manner: As an assistant holds the leg with the knee extended and the thigh in 20 degree abduction and full extension but neutral as regards rotation, the operator transposes the muscle mass so that it lies in greater part posterior to the coronal plane of the trochanter and pulls its free end as near the iliac crest as its length permits. This point is the site selected for the new origin of the muscle. Usually the muscle is too short to reach the iliac crest, but occasionally it can be attached there. The bed for insertion of the muscle is prepared as shown in the sketch (fig.). A slot ¼ inch wide and 1½ to 2 inches long (0.6 cm. wide and 4 to 5 cm. long) is cut in the outer table of the ilium. The superior margin of the slot is levered gently outward after the making of divergent cuts ½ inch long at the two ends of the slot.

5. The free ends of the silk traction sutures are passed by a curved needle into the slot to emerge from drill holes in the outer table of the ilium. The free end of the muscle mass is then carefully drawn into the slot and the sutures are tied as the leg is held in the corrected position.

6. The wound is closed in layers and the leg is immobilized in plaster in the abducted, fully extended and slightly externally rotated position.

AFTER-CARE

Assisted motion and gentle physical therapy may be instituted as soon as the wound is well healed. Full weight bearing is permitted four to six weeks after operation. The extended, abducted and externally rotated thigh may be maintained in this position at night for as long as the surgeon deems advisable, but prolonged use of retentive apparatus is usually unnecessary.

RESULTS

Each of the patients operated on by me over the past ten years has obtained a satisfactory result so far as correction of the flexion–internal rotation deformity is concerned. Two additional patients whose cases have already been reported in the literature [5] have also had satisfactory results. The effect of the operation is most easily estimated by comparing preoperative and postoperative motion pictures of the patient in the act of walking. Owing to the fact that I am in military service, my records are not now available, and the exact date of the first operation, the number of patients operated on and other data cannot be ascertained at the present time. The operation rests on sound theoretic considerations; it is not difficult and in my hands it has yielded results superior to those obtained from other methods.

(The opinions and assertions contained in this article are the private ones of the writer and are not to be construed as official or as reflecting the views of the Department of the Navy.)

5. Green, W. T., and McDermott, L. J.: Operative Treatment of Cerebral Palsy of Spastic Type, J. A. M. A. **118**:434 (Feb. 7) 1942.

NOTES ON AN EARLY BONE CYST

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Solitary bone cysts are common, but serial roentgenograms showing their early rate of growth are not numerous, and seem worthy of publication.

The Institute of Child Welfare of the University of California, in Berkeley, has been closely following the development of certain pupils in schools, and among

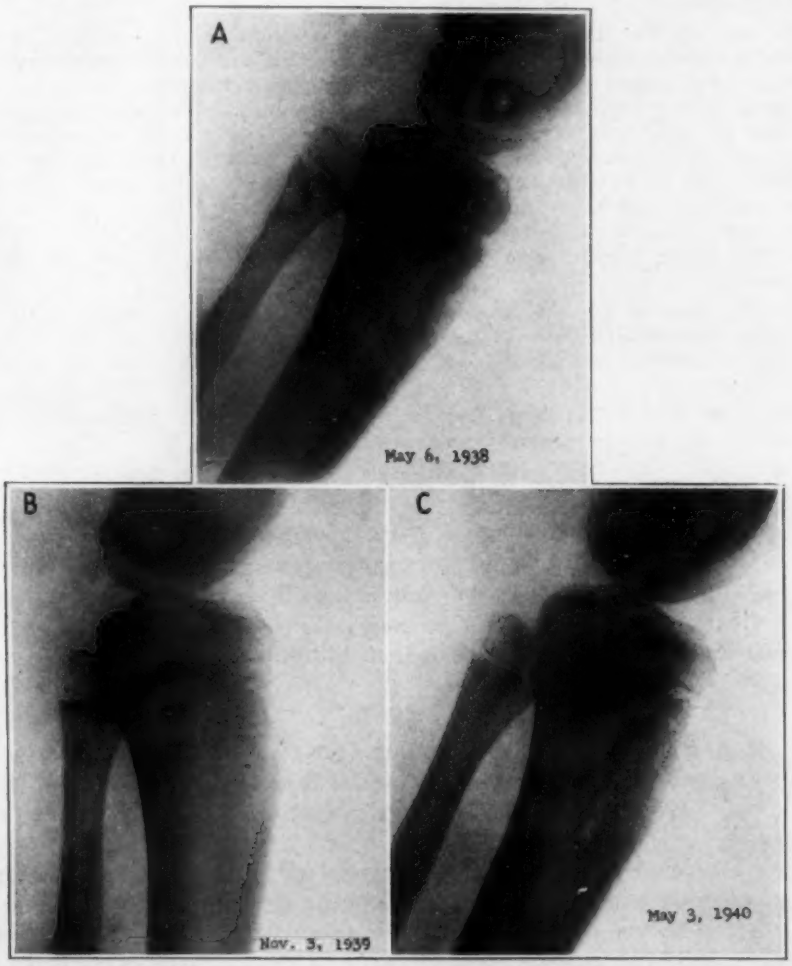

Fig. 1.—*A*, roentgenogram of the tibia that later was to show a bone cyst; the bone appears entirely normal. *B*, roentgenogram taken eighteen months later, showing a tiny bony defect near the medial surface of the tibia. *C*, roentgenogram taken a half year later than *B*, showing a bone cyst in the same location.

the methods used is the taking of serial roentgenograms of the left knee. In the course of the routine studies the cyst to be reported was discovered, and the Institute permitted me to use its data.

REPORT OF A CASE

D. C., the boy in question, was a healthy active lad who had successfully weathered the usual childhood diseases. He had had no major accidents and no injury of any kind to the region of the left knee. The first roentgenograms were taken on May 6, 1938, when the boy was 9½ years of age. Both the anteroposterior and lateral views included the desired area of the tiba and showed the bone to be entirely normal (fig. 1 *A*). The second roentgenograms were taken on Nov. 3, 1939, when the boy was 11. The anteroposterior view did not satisfactorily include all the desired area, but the lateral view did (fig. 1 *B*). A tiny bony defect was seen. The next roentgenograms were taken a half year later, on May 3, 1940. In these

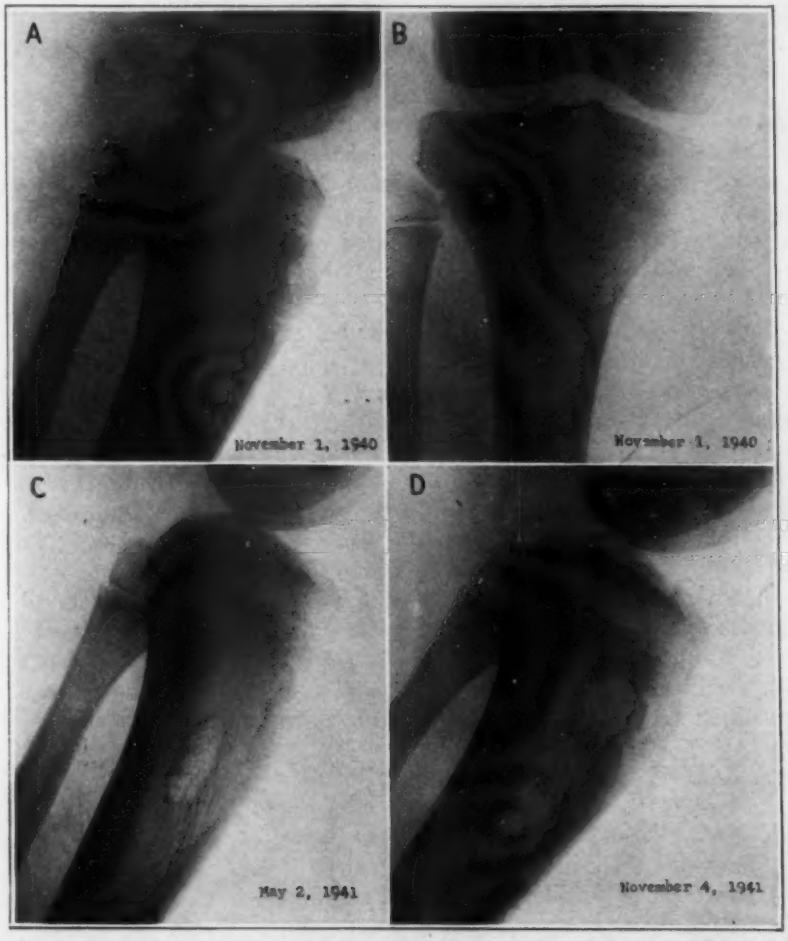

Fig. 2.—*A, B* and *C,* roentgenograms taken six months (*A* and *B*) and one year (*C*) after that shown in figure 1 *C*. Three months later the cyst was treated surgically. *D,* taken two and a half months after operation, shows appearance of satisfactory healing.

a small area of rarefaction about 13 by 3 by 3 mm. in size (beginning of a cyst) could be seen near the medial surface of the tibia, commencing about 3 cm. distal to the proximal epiphysial line (fig. 1 *C*). The anteroposterior view included only a portion of this cyst. Other roentgenograms taken on Nov. 1, 1940 and on May 2, 1941 showed considerable increase in the size of the cyst (fig. 2 *A, B* and *C*).

On Aug. 15, 1941 the cyst was opened, curetted, swabbed with 50 per cent zinc chloride solution, washed with alcohol and closed. The wound healed promptly. The last roentgenograms taken about two and one-half months later, on November 4, showed satisfactory healing (fig. 2 *D*).

The scrapings obtained at operation were immediately sent to the Alta Bates Hospital Laboratory, which made the following report:

"Macroscopic examination: The specimen consists of many small masses of hard and soft red tissue, weighing about 5 Gm. in all. Sections are taken for microscopic study.

"Microscopic examination: There is marked absorption of bone, and the soft tissue is of two distinct types. Some of the soft tissue is composed of a rather dense, regular, hyaline connective tissue, while the rest is composed of very cellular tissue containing many giant cells. The other cells are oval or spindle shaped with pale nuclei like endothelial nuclei. They are not malignant in appearance. The tissue is very vascular, and a considerable amount of brown blood pigment is present.

"Diagnosis: Giant cell tumor of bone. "Signed: David Singman, M.D., Pathologist."

COMMENT

This cyst was located in one of the three commonest sites for such lesions, which, according to Geschickter and Copeland,[1] are, first, the proximal portion of the femur, second, the proximal portion of the humerus and, third, the proximal portion of the tibia. The authors cited have described the acute bone cyst of not more than six months' duration as bordering "directly on the epiphyseal line on its shaft side." The present cyst was located obviously in the same general position, but even when first discovered it did not seem to border directly on any epiphysial line.

The data on hand are manifestly insufficient to permit exact determinations of the rate of growth in volume of the cyst, but since the roentgenograms were made under similar routine conditions, one could (by measuring in millimeters the three dimensions of the cyst as shown in each of the three sets of roentgenograms taken in May 1940, November 1940 and May 1941) get figures which would indicate not the actual volumes but approximately the relative sizes of the cyst on the two latter dates for comparison with that on the first date. The product of the three dimensions for May 1940 was about 126, that for November 1940 was about 500 and that for May 1941 was about 1,540. This seems to indicate that the volume of the cyst increased about 300 per cent during each of these two six month periods.

At no time previous to the operation did the boy have the slightest pain, discomfort or abnormal feeling of any kind about the lesion, nor was there any deformity, swelling or other local sign. The discovery of the cyst was entirely due to the fortunate routine roentgen examinations.

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1. Geschickter, C. F., and Copeland, M. M.: Tumors of the Bone, New York, American Journal of Cancer, 1931.

DYSMENORRHEA: THE RESULT OF A POSTURAL DEFECT

LIEUTENANT H. E. BILLIG JR. (MC), U.S.N.

"Menstrual cramps and backache" have persistently played a prominent role among the chronic complaints that periodically interfere with feminine activities. Numerous investigations, in a search for causes and cures, have left a variety of theories which have obscured the factors involved.[1] By the use of fundamental methods of physical diagnosis, accurately applied, certain pertinent factors not heretofore generally recognized have been brought to light concerning dysmenorrhea.

In the examination at the time the complaints are present it can be noted that:

1. The localization of the pain of "abdominal cramps" is along the twelfth dorsal or the first lumbar spinal nerves or both, or along their branches, the ilioinguinal and iliohypogastric nerves, or along all these. Hence the symptoms are localized in relation to the peripheral nerves in the abdominal wall and not in relation to intrapelvic structures.[2]

2. The localization of the pain in the back is in relation to the region of attachment of ligamentous skeletal structures, e. g., ligamenta flava.

3. There is a restriction of the range of excursion in the posterior tilt of the pelvis in relation to the legs and the spine. If the posterior tilt of the pelvis is forced past the point of restriction by manipulation, the pain in the back and in the lower abdominal region is exacerbated. The manipulative testing is done by forced adduction in hyperextension of the leg on the pelvis with the patient lying face down on the table and the pelvis fixed firmly to the table by means of a strap placed at the level of the tip of the sacrum. The complaints can be elicited by this manipulative testing in any other phase of the estrus cycle even though the woman has never had them at other than a specific time in relation to the menstrual flow. The restriction of motion can be determined by this manipulative testing to be ligamentous and not bony. Careful test use of estrogenic substances reveals that the restriction of the posterior pelvic tilt is reduced when the estrogenic level is raised. This perhaps explains why the signs and complaints are most frequently present near the onset of menstrual flow, a time in the estrus cycle when the estrogenic level is lowered.[3]

A review of the illness in question in large series of cases of dysmenorrhea reveals that in addition to the "menstrual cramps and backache" there are a number of concomitant complaints frequently recorded. These include:

1. Aching and pain along the course of branches of the sciatic nerve, chiefly in the posterior tibial region.

2. Aching and pain in the occipital region of the skull (usually termed "headache") and the posterolateral region of the neck, sometimes radiating out to

1. Fremont-Smith, M.: Essential Dysmenorrhea, New England J. Med. **226**:795-798 (May 14) 1942.
2. Billig, H. E., Jr.: Back Pain and Neuritis, Am. J. Clin. Med. **48**:96-99 (April) 1941.
3. Hisaw, F. L.: Corpus Luteum Hormone: Experimental Relaxation of Pelvic Ligaments of Guinea-Pig, Physiol. Zoöl. **2**:59-79 (Jan.) 1929.

the shoulders and arms. These complaints can also be exacerbated in testing by placing a manipulative tension on the ligamentous structures, past and through which the nerves supplying these regions course.

A postural defect of contracted ligamentous bands restricting the normal range of spinal-pelvic-femoral postural excursion is found present. The shortening or contracture of the ligaments causes compression of nerve pathways producing irritation of peripheral nerves. This irritation gives rise to painful symptoms in the region of the distribution of these nerves and is proposed as the mechanics involved in producing symptoms of dysmenorrhea.

Factors predisposing to the development of the postural defect include slumped posture in childhood; poor adult postural habit; occupational postural habit; slumping due to debilitation after illness; structural bony defects; paresis or paralysis; visceral irritations, such as endometriosis or pelvic inflammatory disease; endocrine shortcomings; fascial contracture subsequent to traumatic fascial strain; arthritis; lesions of bones and joints.

Treatment consists in freeing the nerves of their irritative compression by correcting the postural defect. This is done through precise routine ligamentous stretching exercises carried out by the patient, which result in progressive, accumulative lengthening of the ligaments involved.

The patient stands with heels and toes together about 18 inches (45 cm.) from, and with side to, a wall. The elbow is placed against the wall at shoulder level with the forearm and hand resting on the wall. The heel of the opposite hand is placed in the hollow on the posterior aspect of the greater trochanter of the hip. The shoulders are kept in a line with the elbow perpendicular to the wall and not allowed to shift forward. The knees are kept completely extended and not allowed to flex. The abdominal and gluteal muscles are strongly contracted while the hips are shifted slightly forward and in toward the wall, aided by pressure on the greater trochanter of the femur from the heel of the hand. The objective is to force the extent of sideward and forward shift of the hips in toward the wall far enough not only to place a strain on the contracted ligamentous bands but to gain a progressive stretch as well. This accentuates the symptoms momentarily at each stretch. The stretchings are done routinely three times to each side at three periods daily, a total of nine stretchings to each side every twenty-four hours. When these stretchings are being taught, the patient must return for instruction at two day intervals several times, with weekly observations thereafter, else the stretchings will frequently be done incorrectly or incompletely and the expected benefits will not be obtained.

With consistent stretching, complete lasting relief will usually be obtained (1) in mild cases after about one month, (2) in moderately severe cases after about two months and (3) in severe cases after about three months. An occasional patient will need the additional aid of estrogenic therapy. After relief has been obtained the patient is advised to continue the stretching exercise sufficiently to "keep stretched out," in order to prevent recurrence.

The method has been applied and evaluated in several health services and by several observers as follows:

For nearly three years the stretchings have been used routinely in the Womans Student Health Service at the University of Southern California, in Los Angeles, under the supervision of Prof. Lucile Gruenwald, assistant supervisor of physical education for women. Professor Gruenwald reports:

> . . . every girl who has conscientiously done these stretchings has obtained complete relief. We are very enthusiastic and are making knowledge of this method available to our classes for physical education teachers.

Mr. John C. Burke, assistant director of the health service section of the Los Angeles City School System, reports on the use of this method as follows:

> During the last three months of the past school year, ten senior high and three junior high schools incorporated your special exercise program in their corrective procedures. There were 625 girls enrolled, chiefly the severely affected. Of these 80 per cent were reported cured or improved. The other 20 per cent were those who did not follow the program scheduled or who were indifferent. Our teachers are very enthusiastic about the exercises and are encouraged because of the outstanding results obtained. We are including them in the corrective physical education program of all our junior and senior high schools.

For the past two years the method has been in effect at the Parent-Teacher Association Health Center for the Los Angeles City Schools under the guidance of Supt. R. P. Deakers, M.D., and the chief supervising nurse, Mrs. Ethel L. Huston, P.H.N. They report that cooperation of girls under treatment has been good and that relief of the complaint has been effected in all those who cooperated.

The Twentieth-Century Fox Studios have, for the past year, used the method under the supervision of Mrs. Kathleen Ridgeway, who reports routine alleviation of the complaint in her cases and states that the loss of innumerable work days due to this complaint have thus been eliminated.

Defense industries, faced with the problem of keeping an increased percentage of women workers on the job, have installed the method in order to eliminate periodic off-duty days. Dr. A. C. Dick, medical director of Consolidated Aircraft Corporation, of San Diego, Calif., arranged for instruction of the plant nurses and matrons in the use of the method. Dr. Dick reports that in every instance in which the woman has done the stretchings consecutively for forty-five days there has been marked relief.

SUMMARY

The postural defect of contracted ligaments giving rise to irritative compression of nerves is proposed as the cause of the symptoms of dysmenorrhea.

A practical method of releasing the irritative compression of nerves by loosening the ligaments involved through accumulative routine stretching is outlined.

COMMENT

Although a clinical method of relief from dysmenorrhea is at hand, the subject awaits adequate explanation of the physiologic mechanism of the localized radiation of pain along the course of a peripheral nerve. The exact physiologic-anatomic mechanism of shortening and lengthening of ligaments (e. g., ligamenta flava or the iliotibial band) needs explanation.

EARLY MOBILIZATION OF FRACTURES OF THE UPPER END OF THE HUMERUS

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The following is a brief report of 97 cases of fracture of the upper end of the humerus taken from the orthopedic services of the Charity Hospital at New Orleans. The plan of treatment followed that of M. K. Lindsay and Carolyn M. Brown;[1] P. D. Wilson[2] and A. C. Schmidt.[3]

The fractures were located as follows: surgical neck, 61; greater tuberosity, 17; anatomic neck, 11; lesser tuberosity, 2; shaft, 6. (In approximately 50 per cent of all cases the fractured bone was comminuted.)

The methods of reduction required in some of the cases will not be discussed, but the fixation and the subsequent treatment to regain motion were carried out in accordance with the following methods:

The fractured extremity is supported by an axillary pad, with the arm fixed to the side of the body by a wide bandage encircling the upper arm and the body, leaving the elbow free. The wrist is supported by a cuff suspended from the neck. When in bed, the patient is placed with the body at approximately an angle of 35 degrees. It is important that the patient at no time be placed in the horizontal position. The physical therapy as carried out by the physical therapy department at Charity Hospital is as follows:

The day after the fracture mild, dry heat is applied to the shoulder, elbow and hand without disturbing the bandage. On the fourth day after the application of heat the bandage is removed with the patient in a standing poistion. Light effleurage of the entire extremity and shoulder is administered to relieve pain and reduce swelling, and at the same time the forearm is gradually extended. Following the massage, the patient is instructed to flex the trunk, bend the knee on the affected side and permit the affected arm to fall forward completely relaxed, so that passive abduction and forward flexion are secured. The patient now moves the body in a circular motion so that passive circumduction of the shoulder occurs. The range of motion at first is small and is gradually increased. After five to seven days active motion gradually replaces passive motion. Strict supervision of this treatment is essential and should be carried out by a competent physical therapy technician. At the end of the treatment the axillary pad and the body bandage are replaced. Three or four weeks later the abduction pad and the bandage are discarded, and the forearm cuff, a week to ten days later. At the end of four weeks all active motion of the shoulder is encouraged. Treatment is continued daily for two weeks, then three times a week for two weeks, twice a week for three weeks and once a week until satisfactory range of motion has been obtained. The average number of treatments required in the series of cases reported was twenty-three.

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1. Lindsay, M. K., and Brown, C. M.: Relaxed Motion in the Early Mobilization of Fractures and Dislocations, in Mock, H. E.; Pemberton, R., and Coulter, J. S.: Principles and Practice of Physical Therapy, Hagerstown, Md., W. F. Prior Co., Inc., 1932, vol. 3, chap. 16.

2. Wilson, P. D.: Experience in the Management of Fractures and Dislocations, Philadelphia, J. B. Lippincott Company, 1938.

3. Schmidt, A. C.: Physiotherapy Rev. **19**:65 (March-April) 1939.

The range of motion is graded as follows: 0 to 25 equlas poor; 25 to 50 equals fair; 50 to 75 equals good; 75 to 100 equals excellent.

The results obtained have been as follows: Poor in 6 cases, fair in 17, good in 32, excellent in 27 and undetermined in 15.

Lack of cooperation and failure to report back for treatment accounted for a large majority of the "poor" and "undetermined" results.

This method in my opinion is far superior to the old method of long immobilization because no elaborate equipment is necessary, patients do not need to remain in bed, they are comfortable almost from the start of treatment, pain is promptly relieved and later complications, such as stiff joints and traumatic arthritic changes are seldom seen.

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PRONE POSITION FOR EXPOSING THE MEDIAL MENISCUS OF THE KNEE JOINT

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Numerous types of incision have been described in the past for removal of the menisci of the knee joint. There is first the utility or paramedian incision which skirts the mesial border of the patella and divides the tendon of the quadriceps muscle. This incision, while it is used often, has the objection of causing a long disfiguring scar.

Proper names are deservedly disliked in medical literature, but the following names have been popularly attached to types of incision for removal of the internal semilunar cartilage of the knee joint. The curved incision described by Jones (fig. 1, *1*) is possibly the most popular for excision of the medial meniscus of the knee joint. The Jones [1] incision is "slightly curved and extends from an inch within the lower angle of the patella to one-half inch below the tibial margin, curving more acutely at this point toward the internal lateral ligament."

The Cave [2] incision was described as follows: "The incision begins three-eighths of an inch behind and on a level with the internal epicondyle of the femur. This incision is carried downward and curved gradually anteriorly to a point one-fourth inch below the joint line and then forward to the border of the patellar tendon" (fig. 1, *2*).

Fisher [3] described his incision as follows: "This is a curved incision. The more vertical element of the curved incision coincides with the anterior margin of the internal lateral ligament and the horizontal element curves forward toward the patellar ligament" (fig. 1, *3*).

Bristow [4] uses a simple oblique incision on the anteromesial aspect of the knee joint. His incision is practically transverse.

I do not intend to confuse or complicate the simple task of excising a meniscus of the knee joint by proposing a new incision. In the method to be described, the principal feature is the patient's position on the operating table. The patient is placed in a prone position on the operating table (fig. 1, *4*). The knees are kept flexed on the thighs. First the sound knee is kept flexed by a bandage tied from the ankle to the head of the operating table. Next the operative site is prepared while an assistant holds the leg aloft. Draping of the knee is finished, and the draped knee is kept flexed by tying a sterile bandage from the ankle to the head of the operating table. No tourniquet is used for fear of the development of thrombosis of the popliteal artery. Murray [5] pointed out that bleeding into the knee joint from an incision will be negligible if the patient is operated on in the Trendelenburg position.

1. Jones, R., and Lovett, R. W.: Orthopedic Surgery, New York, William Wood & Company, 1923, p. 34.

2. Cave, E. F.: Combined Anterior-Posterior Approach to the Knee Joint, J. Bone & Joint Surg. **17**:427-430, 1935.

3. Fisher, A. G. T.: Internal Derangements of the Knee Joint, New York, The Macmillan Company, 1924, p. 61.

4. Bristow, W. R.: Internal Derangements of the Knee Joint, J. Bone & Joint Surg. **17**:605-626, 1935.

5. Murray, C. R.: Complicating Factors in Treatment of Injuries to Menisci of Knee Joint, Am. J. Surg. **55**:262-273, 1942.

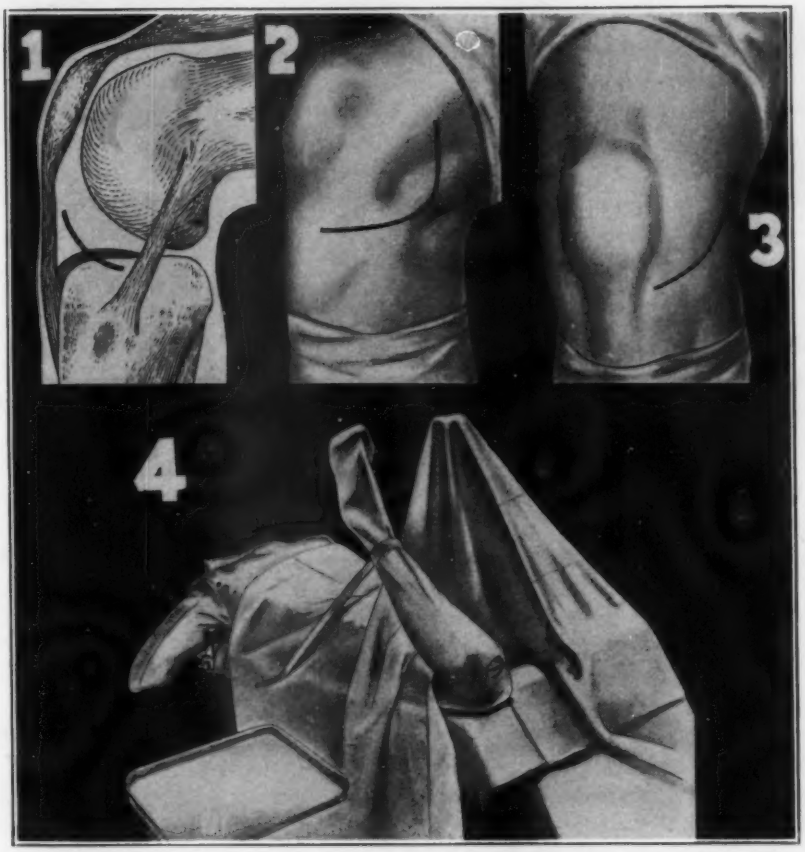

Fig. 1.—(*1*) Jones incision for removal of the medial meniscus of the knee joint; (*2*) Cave incision; (*3*) Fisher incision; (*4*) prone position and transverse incision described in this article.

Fig. 2.—Visualization of the medial meniscus at operation.

With the patient prone and with his knees flexed, the operator makes his incision. I prefer a small transverse incision directly over the proximal end of the tibia. This incision extends along the anteromesial edge of the tibia for a distance of about 1½ inches (3.8 cm.). After the incision is deepened through the superficial and deep fascia, the synovial membrane is incised exactly at the articular surface of the tibia. The torn meniscus can now be visualized and excised. Should insufficient exposure follow the use of the incision, a second incision may be made anterolaterally over the lateral semilunar cartilage. In addition the knee joint may be extended in order to expose the popliteal area for incision. Neither of these incisions has been necessary in the present series.

I believe that by operating with the patient prone the posterior portion of the meniscus can be seen more easily than by an incision of similar size with the patient in a supine position. In the prone position the knee joint can be completely flexed. The tibia can be used as a lever by the assistant to abduct the knee joint; thus the mesial compartment of the knee joint can be fully visualized.

In the description the preparation for surgical intervention may seem complicated and laborious, but this is not actually the case. The patient should be so placed that his knees project just beyond the end of the operating table. (The leaf of the operating table should be dropped before the patient's leg is prepared.) Shoulder bars will prevent the patient from sliding toward the head of the table. The foot of the operating table is raised considerably.

An objection that may be raised to operating on a patient in the prone position is the difficulty of administering an anesthetic. I encountered no difficulty when spinal anesthesia was used.

Fifteen patients have been operated on in the manner described. The methods of immobilizing their knees postoperatively have varied. No fixed conclusion has been reached as to the best method of immobilizing knee joints after arthrotomy.

SUMMARY

The prone position for excision of the medial meniscus of the knee joint has been described. Exposure of the posterior half of the meniscus is facilitated by this procedure.

NEW ASPECTS OF SPINAL INJURIES

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This article has for its purpose the recording of (1) points concerning the treatment of spinal injuries on which general agreement has been reached, (2) points on which there still exists considerable divergence of opinion and (3) a number of new aspects which may be considered addenda to the general subject of spinal injuries.

The treatment of fractures and fracture-dislocations of the spinal column from remote antiquity to the present day divides itself naturally into four periods. Historical data revealed by the findings of Dr. George Bennett show throughout periods covering millenniums many an attempt at immediate reduction, some of which apparently were completely successful. All such attempts, however, were done blindly, and photographic proof obviously is completely lacking. Professor Roentgen's discovery in 1896 provided the only exact criterion for diagnosis and perfection of result. The orthopedic surgeon had been treating tuberculosis of the centrum for ages, and many had been the attempts to correct the hunchback. The failure of the centrum to repair its defects, however, led to a misapprehension regarding the callus-forming ability of the vertebral body, so that any attempt to open up a collapsed centrum was frowned on if not actually forbidden. Had it not been for this very naturally acquired misconception, the problem of the crush fracture of the centrum probably would have arrived at a much earlier solution. The ancients experienced no such conditioning, and by and large it might be said that they treated fractured spinal vertebrae more rationally than did, later, surgeons who operated during the intermediate modern period when the association complex of pathologic destruction of the substance misled them into funny ideas about the circulation of the centrum being peculiar. The idea that the centrum or body of the vertebra constituted the one outstanding exception to spontaneous callus formation became fixed.

The modern conception of Kümmell's disease served to intensify the illusion. Kümmell's disease was thought to be idiopathic or spontaneous progressive atrophy, its cause being vaguely related to injury. Subjected to the light of adequate roentgenography another bogy was dispelled. Kümmell's disease as such has now disappeared, the condition to which that name was applied having taken its proper position as an unrecognized or improperly treated fracture of the centrum. The subsequent atrophy is now interpreted as nothing more than nonunion due to motion between fragments with resulting failure of anastomosis of vessels between the two main fragments.

And then came fear. Fear of overhyperextension sufficient to disrupt the spinal canal, sufficient to induce paralysis. Tests of the tensile strength of the anterior longitudinal ligament, together with a study of its structure and of its behavior when fracturing forces were applied to the spinal column, demonstrated its relatively great strength. By and large one may say that the anterior longitudinal ligament is secure against horizontal severance as a result either of fracturing forces or of hyperextension reduction. With but two exceptions, the check strap function of the anterior longitudinal ligament can be depended on. The exceptions consist of the rare case

of hyperextension fracture and the case in which the horizontal element or shearing force has irreparably damaged the cord.

Seventeen years of experience in actual and immediate reductions of fractures and dislocations of the spinal column have served to bring about general agreement on a number of points. These points may be listed as follows:

1. Hyperextension is as generally applied in the reduction of fractures of the spinal column as is straight line traction in the reduction of fractures of long bones.
2. The vertebral centrum can be depended on to form callus after fracture as promptly as any other osseous structure.
3. In cases of paralysis laminectomy as a decompressive procedure occupies a place distinctly secondary to that of hyperextension.
4. The Queckenstedt test is an invaluable means for the determination of spinal subarachnoid block before and after hyperextension.
5. Skeletal traction, such as that obtained with the Crutchfield tongs, is an invaluable therapeutic adjunct for crush fractures or fracture-dislocations of the cervical part of the spinal column.
6. The intact posterior arches of vertebrae when hyperextended are capable of sustaining the imposed weight of the torso without the aid of the centrum; thus during part of the convalescent period the patient is made safely ambulatory.
7. The anterior longitudinal ligament when interpreted correctly acts as the main reducing medium as well as the main check strap opposed to excessive hyperextension.

At the present writing a number of points of disagreement may be mentioned. First among these points is that of convalescence. The questions of a rule of thumb regarding the amount of time spent recumbent and the amount of time ambulatory, the total time necessary for callus formation and the criteria by which one may judge the integrity and structural strength of callus have called forth widely divergent opinions. From the one extreme of allowing the patient to be ambulatory in a hyperextension jacket immediately after reduction to the other in which he is not allowed to be foot loose and free for six months or longer, many intermediate courses are practiced. Were it possible to exhibit adequate detail of the posterior arch roentgenographically, ambulatory treatment immediately after reduction would be understandable. Considerable evidence, however, exists to show that fissure fracture of the posterior arch occurs regularly, and with the presence of such a fracture, the possibility of a false joint with excessive callus in the articular processes and pedicle sufficient to encroach on nerve roots seems obvious. In my estimation weight bearing should be prohibited up to the time of differentiation of fibrous tissue into bone—in other words, approximately six weeks. On the other hand, results in some 250 cases of crush fracture of a vertebra demonstrate that if the rule of thumb of "six weeks recumbent and six weeks ambulatory in adequate hyperextension" is followed, the sequela of pain in the injured area does not occur nor is there subsequent wedging of the vertebra following the removal of the cast three months after fracture. The general rule therefore is that the patient after reduction of the fracture and application of an adequate hyperextension jacket is allowed freedom in bed to move about in the horizontal position as he pleases but is not allowed to sit up or stand up for six weeks and that then, provided his jacket fits properly, he is not only allowed but is encouraged to walk, as soon

as he can, up to two miles a day in order to induce structural trabeculation in the amorphous callus. It is found regularly and without exception that at the end of three months from the time of fracture an ordinary crush centrum of the vertebra has developed so sound a callus that no fear of a recurrence of collapse of the body need be entertained.

The other main point of disagreement is the manner in which reductions of compression fractures are done. A great variety of methods, all depending on hyperextension, are being used, the Watson-Jones method possibly as much as any. By using the standard hospital bed in reverse, the spinal column can be gradually hyperextended by simply turning the crank. Various types of jacks are

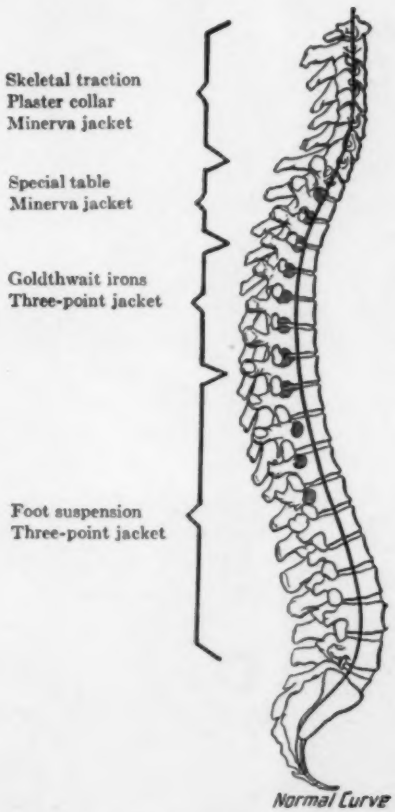

Fig. 1.—Difference in method indicated by difference in anatomy.

used by others. My experience in this connection is that the jack is very traumatizing, is extremely painful, requires the use of an opiate or an anesthetic and produces severe distention. Another method reduces the fracture by laying the patient supine, putting a band crosswise underneath the fractured area and hyperextending simply by elevating the band. Gradual methods obviously must be retained for cases of fracture-dislocation with paralysis in which hyperextension cannot be used or in which there are multiple other fractures and the spine meanwhile must be hyperextended. In these cases the standard adjustable hospital bed will suffice or a Rogers frame may be used. Rogers, Dunlop and Jones all have shown excellent results with their individual methods. After having tried all the methods mentioned, I have returned to foot suspension because of its being the simplest and

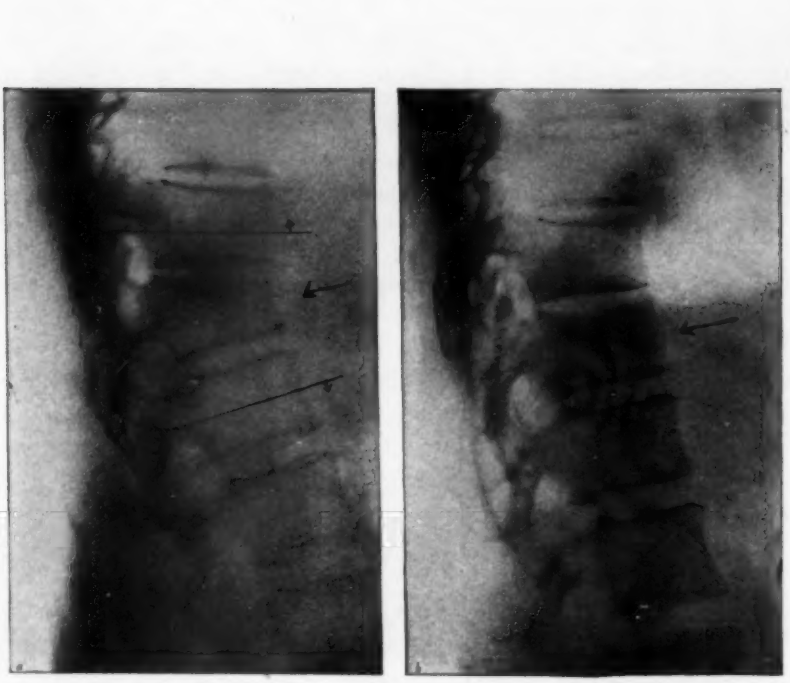

Fig. 2 (case E. G.).—(*a*) Typical crush fracture of the first lumbar vertebra. The levers illustrate the traction and the countertraction exerted by the vertebra above and that below the affected one. (*b*) Typical reduction by foot suspension.

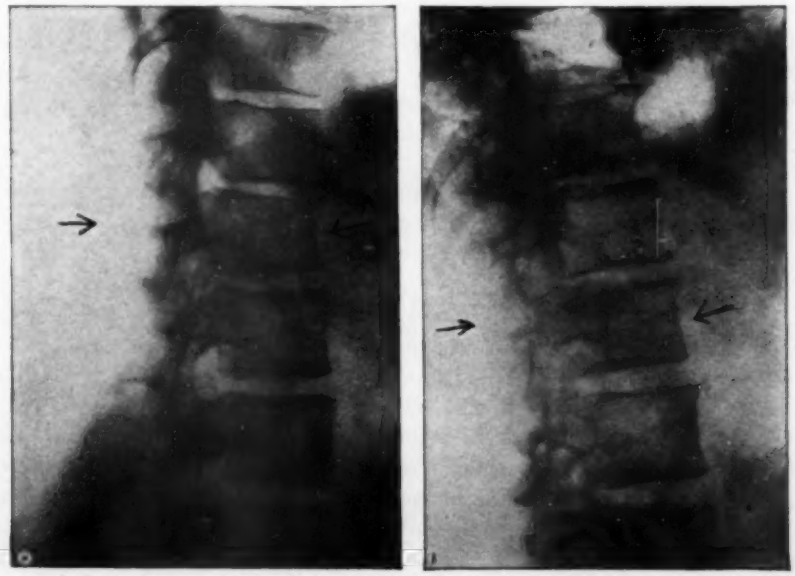

Fig. 3 (case A. H.).—(*a*) Very moderate uncomplicated compression of the first lumbar vertebra. (*b*) Result three months after reduction with Goldthwait irons. Note the complete restoration of the anterior vertical diameter.

the most effective as measured by ease of operation, degree of reduction and the critical factor of protection of the posterior arch. No opiate or anesthetic is used, and the patient's discomfort at the point of fracture is usually relieved during this simple gravity suspension.

In a personal communication from Dr. Gallie, of Toronto, Canada, I learned of a method which can be extemporized where the ordinary medical facilities are not available. If one recalls that hyperextension by foot suspension involves nothing more drastic than the child's game of wheelbarrow, fears concerning foot suspension should be dispelled. Dr. Gallie stated that treatment in his first case was carried out in the following manner: "A small box was placed under the chest of the patient, he lifted the feet to his shoulders and rested them there while an assistant put on a plaster jacket."

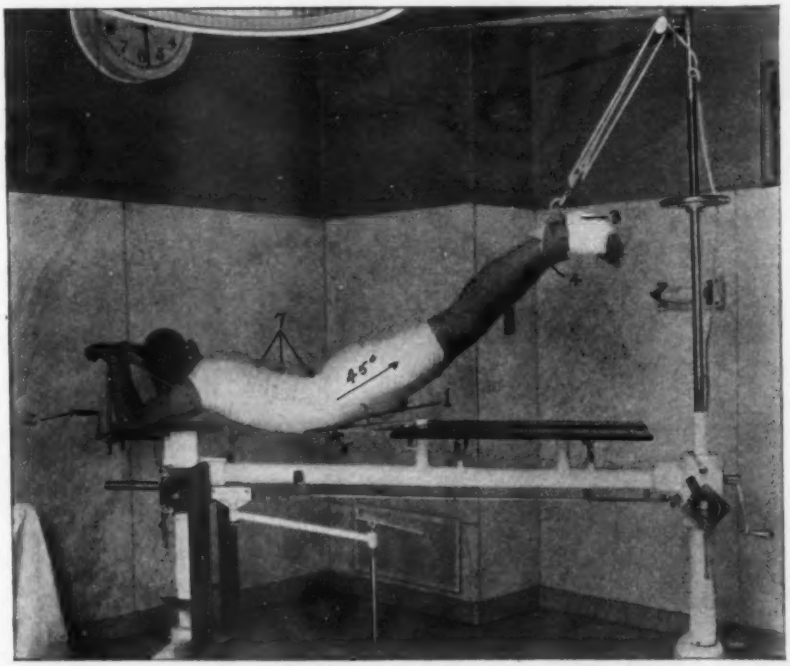

Fig. 4.—Points in a typical reduction of an uncomplicated thoracolumbar crush fracture: *1.* Ample clearance between the anterior spines and the hammock affords an index of adequate hyperextension. *2.* The hammock may be lowered with a crank to increase hyperextension further. *3.* Sheet wadding cushions the holder. *4.* A holder loop of canvas with a ring by which to suspend the patient is shown. *5.* A canvas hammock is to be noted. *6.* The weight of the chest is carried by the hammock. *7.* Maximum hyperextension is obtained at the region involved.

SOME NEW ASPECTS OF SPINAL INJURIES

Several new accretions to the subject of spinal injuries have become apparent. These seem worth recording at this time.

1. Under the heading of roentgenographic concealment in relation to the *degree* of severity of the injury, new interpretations seem important.

2. The tests for the tensile strength of the anterior longitudinal ligament bear an important relation to the general subject and to the various technics employed to reduce fractures of the spinal column.

3. A method is presented for diagnosing by inference a fracture-dislocation in which there is a single jumped process.

4. A technic by which such a fracture-dislocation may be reduced completely is described.

5. The diagnosis and the treatment of a hitherto unrecognized but regularly occurring type of cervical luxation are presented.

By this time it has become obvious that the vast majority of crush fractures and fracture-dislocations of the spinal column occur as the result of a hyperflexion mechanism. The preponderance of the automobile accident as a cause of these fractures has helped to an understanding of the usual fracturing force. In a head-on collision the continuing forward momentum of the parts of the body that are not braced when the vehicle has come to a full stop results in a whip lash mechanism. The forward momentum of either the head alone or a part of the torso continues on the lower fixed section of the body at the moment of impact of the collision. Immediately following the hyperflexion there is a spontaneous recoil in extension. The complete action resembles a whip lash. The recoil mechanism is sufficient in some cases to reduce a dislocation spontaneously as evidenced by cases showing complete neurologic involvement from the cervical region downward, in spite of the first roentgenograms showing apparently negligible damage or no damage at all. Likewise, the spontaneous partial reduction of a crush fracture of the lumbar area is accomplished by proper first aid handling—e. g., by rolling the patient over and carrying him in the prone position—or simply as a result of his rising on his elbows in this position. Either or both of these actions exert enough extension to partly restore vertical diameter. It is clear, therefore, that the first lateral roentgenogram cannot be expected to show the full degree of involvement of the vertebral arch since it is not known how much spontaneous reduction already has taken place. The likelihood of involvement of the posterior arch is proportional to the degree of vertical collapse of the centrum. There is considerable evidence from those whose practice it was to expose such fractures for the purpose of immediate fusion that at the time of exposure a good many fissure fractures of the articular processes and laminas were disclosed which otherwise were unsuspected. The following section, therefore, is aimed at clarifying hidden lesions of this type.

ROENTGENOGRAPHIC CONCEALMENT

The diagnosing of lesions of the posterior arch by inference must be resorted to since the roentgenogram cannot be depended on to show even gross lesions involving the pedicles, the articular processes and the laminas. One is frequently tricked by the illusion of a completely normal-appearing posterior arch. Fissure fractures without gross displacement, for instance, are impossible to exhibit by ordinary roentgenography. Figure 5 depicts a portion of a spinal column (obtained at autopsy) in which a number of fractures of the pedicles and articular processes were made with a Gigli saw. The four views of this specimen show but two fractures. It is noted in this connection that the Gigli saw creates a considerably greater defect than a simple fissure fracture.

While it is generally appreciated that the roentgenogram cannot be expected to show all of the lines of fracture in a long bone, it is not so well known that cracks and dislocations of a posterior vertebral arch are much more effectively concealed than those of a long bone because of the very dense bone forming the

accessory processes and because of the number of such processes, particularly in the lateral plane. An Indian hiding behind the trunk of a tree or a barricade would photograph as readily.

A glance at the spinal column shows how impossible it is to hope to reveal the fracture or the dislocation by photography because of the number of processes to

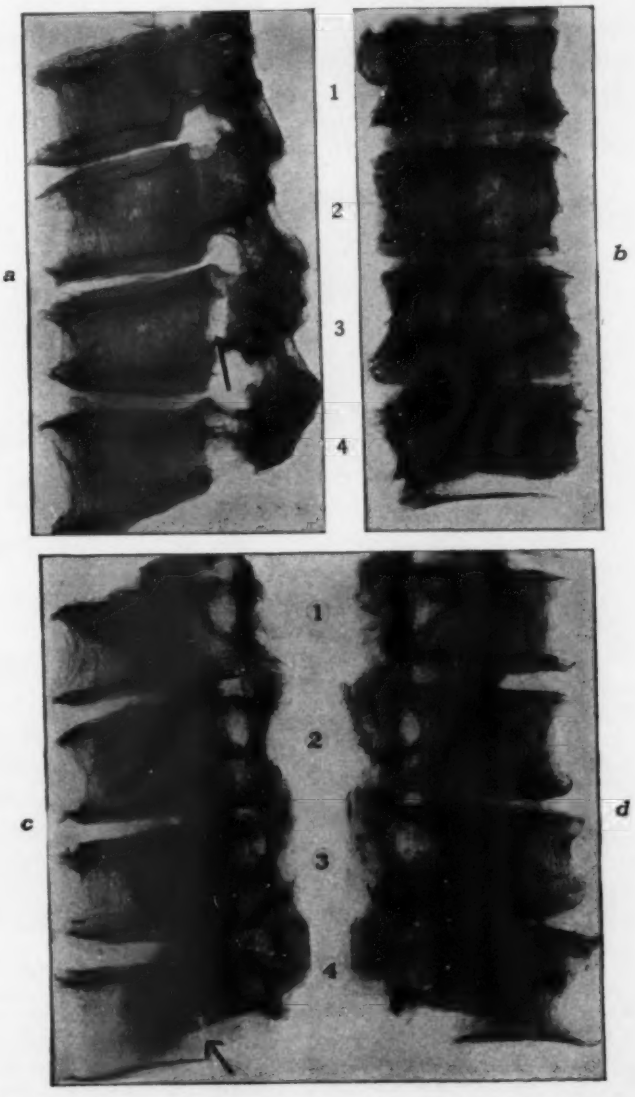

Fig. 5.—Roentgenographic concealment. The letters *a*, *b*, *c* and *d* indicate lateral, antero-posterior, left oblique and right oblique projections of the same portion of a spinal column obtained at autopsy. Fractures were made at various points in the posterior arch with a Gigli saw. A sample of the defect created by the saw is indicated by arrows. The other fractures contain the same amount of defect but are concealed by overlying dense bone. In *a*, *b*, *c* and *d* the states of the four vertebrae are as follows:

Left	Right
1. Intact	1. Articular process fractured
2. Tip of articular process fractured	2. Pedicle fractured
3. Intact	3. Pedicle fractured
4. Articular process fractured	4. Articular process fractured

be penetrated by the rays. In the lateral roentgenogram, for instance, it is necessary to penetrate both transverse processes and four articular processes, besides two pedicles. If a line of fracture shows, it is by the merest chance, and it is necessary for the defect to be large or the dislocation gross.

Roentgenograms taken at an angle of 30 to 40 degrees are more likely to exhibit fracture lines in the articular processes than lateral roentgenograms. The majority of such oblique views, however, cannot be expected to show much more than irregularity of the posterior articulations. The lack of visual evidence of fault in the posterior arch will continue to deceive most observers and will undoubtedly continue to create a false sense of security because of negative findings. No doubt greatly increased caution is exercised by most operators in their approach to frac-

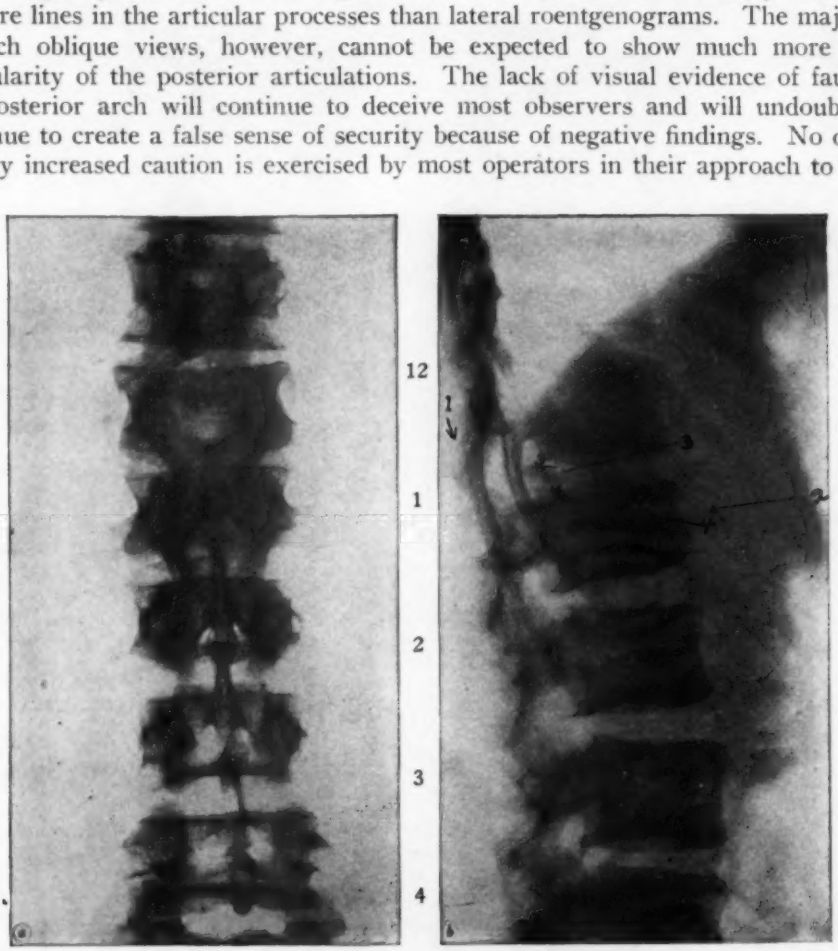

Fig. 6 (case B. G.).—(*a*) Anteroposterior projection of a spinal column showing fracture dislocation of the first lumbar vertebra. Note the lateral angulation, the wide space between the spinous processes, the different alinements of the series of spinous processes above and below the dislocation and the unequal compression of the two sides of the involved vertebral body. Compare with *b*. (*b*) Lateral projection: *1* indicates a gross enlargement of the intervertebral foramen. An articular process of the twelfth dorsal vertebra has dislocated upward and is impaled on the superior articular process of the first lumbar vertebra. *2* indicates the compression unreduced after an attempt at hyperextension. Impinging articular processes do not permit the normal fulcrum of the posterior joint to operate; therefore disimpaction is impossible until the processes have been disengaged. *3* indicates the level of one side of the crushed centrum. *4* indicates the lower level of the opposite side.

ture-dislocations with paralysis; it is the damaged cord in this case which warns the operator. Fracture-dislocations of fully as great magnitude but without paralysis occur regularly. In the case of paralysis one must assume risks which would not be warranted in the case of a simple crush fracture. The greatest danger,

however, is that the operator may do real damage to a fracture-dislocation *without* paralysis. Methods of identifying the dangerous types are as follows:

The roentgenograms must be scanned from the point of view of damage to the posterior arch. With this approach in mind, certain points become immediately obvious. The correlation of a number of these points will frequently decide whether the case is one for manipulative or one for operative procedure. By observing all roentgenograms of spinal injuries in this light, the operator will safeguard himself against disasters due to manipulation.

Figure 6 depicts a case of this kind clearly. The patient presented no neurologic signs whatever. Four points were noted in the anteroposterior view: (1)

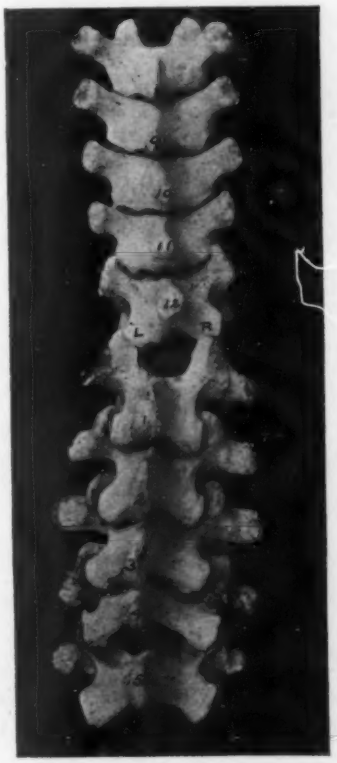

Fig. 7.—Factors entering into the diagnosis of a fracture-dislocation of the lumbar region: (*1*) the lateral tilting of the twelfth vertebra; (*2*) the different alinements of the upper and lower series of spinous processes; (*3*) the lateral angulation of the two spinal segments; (*4*) the rotation localized to the point of dislocation as indicated by the lateral offset of the twelfth vertebra and (*5*) the wide vertical separation of the twelfth and first spinous process.

lateral angulation with its apex at the twelfth interspace; (2) a wide interval between the spinous processes of the twelfth dorsal and the first lumbar vertebra; (3) definite rotation of the entire upper section as indicated by defective alinement of the upper series of spinous processes with those of the lower section; (4) unequal compression of the two halves of the body of the involved vertebra. The patient was a slender boy, i. e., the type of patient with whom roentgenography is at its best and shows the articular processes clearly.

The lateral view brings out additional points: at *1* gross enlargement of the intervertebral foramen; at *2* an appearance of one articular process being impaled

on the one below; at *3* and *4* an appearance of two different levels in the centrum. Wherever such a double shadow of a vertebra appears, dislocation of one articular process must be expected.

Figure *7* is an exact replica of the case just cited. When analyzed, this anatomic specimen shows the lower right process of the twelfth dorsal vertebra jumped and locked in front of the upper right process of the first lumbar vertebra. It also shows almost complete dislocation of the left process.

An analysis of this specimen shows why the angulation, the rotation and the disalinement of the spinous processes, with large interspinous space, all combine to make certain the diagnosis of a jumped articular process and demonstrates conclusively the impossibility of safely reducing such dislocation by manipulation.

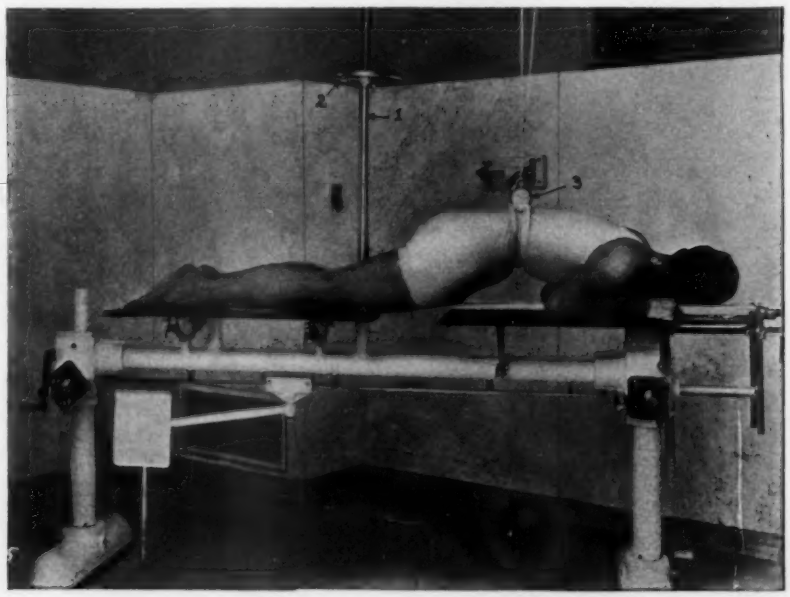

Fig. 8.—Setup for open reduction. Note (*1*) the telescoping post, (*2*) the gear to adjust the level and (*3*) the canvas sling placed at the level of the fracture-dislocation.

It is considered definitely hazardous to attempt any manipulation at all. The sequence of treatment believed to be best for this type of dislocation is as follows:

The patient is mounted on an operating table which breaks in the middle or on a special fracture table as in figure 8. The involved posterior vertebral arch is exposed by the subperiosteal method as in operation for fusion. The laminas and articular processes are exposed in detail. The table is then broken so as to induce the necessary flexion to disengage the jumped process. When the special table is used, a sling is placed transversely underneath the body at the fractured area and flexion is induced simply by elevating the suspension apparatus until the process has room for clearance. A bone forceps is then used to grasp the spinous process of the dislocated vertebra, or a blunt elevator is used to pry the process over. The operator then combines movements of posterior pull with rotation, the table is straightened away, the sling lowered and the dislocation thus rather easily reduced.

With the operative wound still open, the patient is hyperextended by foot suspension, and a lateral roentgenogram is taken in order to see that the centrum is fully restored to its vertical diameter. Obviously, no fusion is necessary in such cases. If, however, the posterior arch is otherwise damaged, fusion may be indicated.

Figure 9 illustrates another case. In this case the area of injury was not opened. The figure shows most of the features necessary to a diagnosis of dislocation of a posterior articular process. The roentgenogram made six months after fracture shows that the patient was saved from further gradual forward

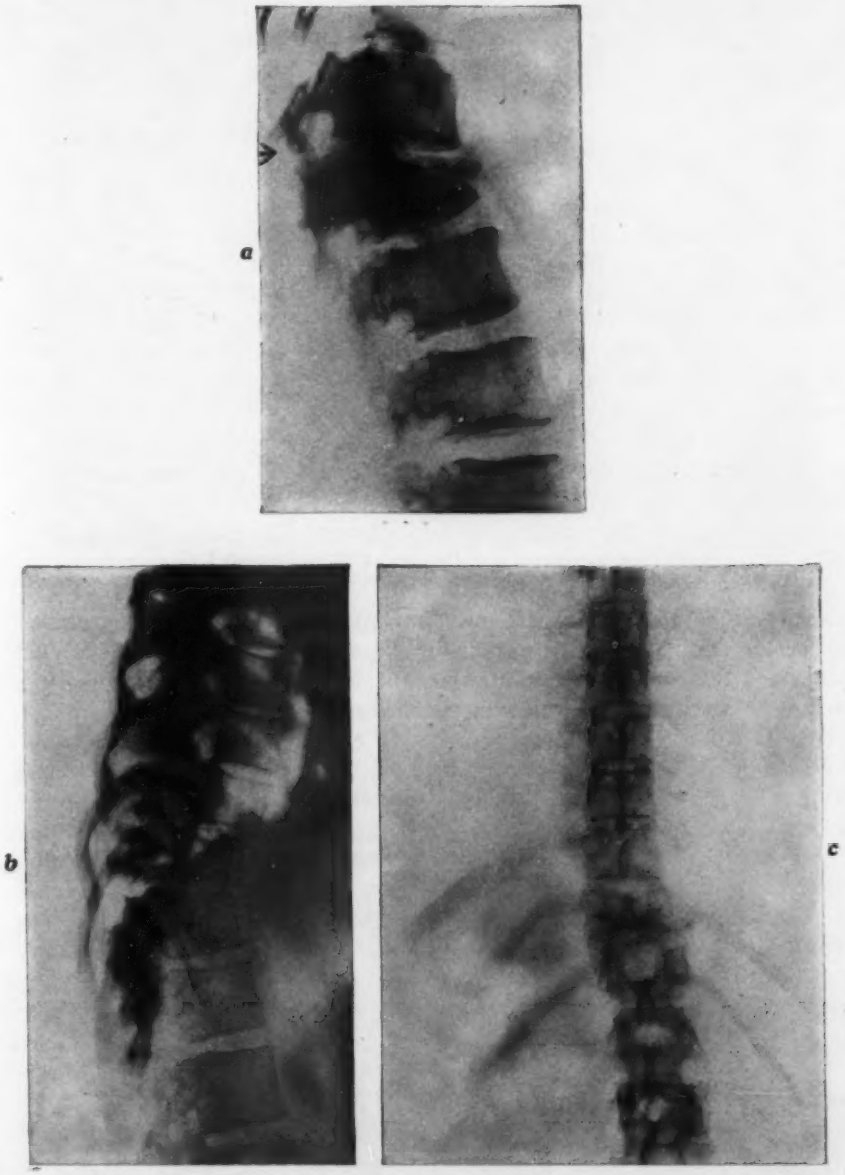

Fig. 9 (case M. P.).—(*a*) Fracture-dislocation without paralysis. Note the gross enlargement of the intervertebral foramen and the articular process caught on the apex of the process below, making closed manipulation futile. (*b*) Lateral view six months after the fracture, showing complete interruption of continuity in the posterior arch. Note the inability to exhibit detail of the articular process, the apparent bony bridge at the anterior portion of the body and the failure of reputedly strenuous attempts at hyperextension to decompress the centrum or to correct the angulation. (*c*) Anteroposterior view six months after the fracture. Note the lateral dislocation and the unequal compression as between the two sides.

dislocation by a bony bridge present between the two vertebrae in front. There is practically no evidence of continuity of structure of the posterior arch.

According to the history, a number of attempts were made to undo the deformity of the centrum by manipulation. Obviously, the centrum could not be opened to its complete height because of the block afforded by the jumped process posteriorly. It must be noted again that neither of the patients in these cases showed any neurologic signs. Obviously, attempts at manipulation in such cases are not only hazardous but futile.

TENSILE STRENGTH OF THE ANTERIOR LONGITUDINAL LIGAMENT

Since the determination of the tensile strength of the anterior longitudinal ligament of man on necropsy specimens demonstrated conclusively the surprising strength of the ligament, all manipulative work has been approached with greater confidence, and a modification of the Walton and Taylor technic for reducing cervical dislocations is justified.

In a paper published in 1938 the results of a series of tests of 7 ligaments obtained at necropsies were recorded. These ligaments were submitted to strains in a testing machine to determine stretch and breaking strength. The results demonstrated an average breaking point of 337 pounds (153 Kg.) with no evidence of stretch. Tests to determine the pounds of pull necessary to reduction showed 80 pounds (36 Kg.) to be sufficient in the cases requiring the most pull. The resulting safety factor is therefore in the ratio of 4 to 1. Except in cases of hyperextension injury or fracture-dislocation, complete assurance may be felt regarding the ability of the anterior longitudinal ligament to withstand the strain of both the initial injury and the reduction.

Descriptions of the Taylor technic for reducing bilateral dislocations of the cervical vertebrae all agree in principle but vary somewhat in detail. If one approaches a Taylor manipulation and visualizes the anterior longitudinal ligament and its known strength, the following modification of the technic seems obvious.

Were it not for this ligament, damage to the cord would undoubtedly ensue as the result of a longitudinal pull. Obviously, it would be a decided advantage to pull the head in flexion. Pulling in flexion, however, puts the maximum traction on the posterior roots of the cord. Therefore, it is decidedly unsafe to pull in flexion. Pulling longitudinally with extension would, in view of the check strap function of the anterior longitudinal ligament, provide a completely safe method of traction, but unfortunately the articular processes will not clear each other since the traction will be exerted principally on the anterior longitudinal ligament and the check strap effect of the ligament will preclude the possibility of a jumped process clearing the summit of the process below. Therefore, pull in the exact longitudinal axis of the body is highly important. A canvas sling placed around the operator's waist or buttocks and attached to the halter allows the operator the best mechanical advantage in handling the head (fig. 10). One hand is placed under the jaw, the other under the occiput, and one of the fingers of the occipital hand is then placed in contact with the cervical spine and its processes to determine crepitus. Ordinarily, distinct crepitus can be felt when the articular processes disengage. When this occurs with full traction still maintained on the head, the head is brought into extreme hyperextension. A lateral roentgenogram is then taken. If reduction has not taken place, another attempt, using more traction, should be made. It is interesting at this point to know how much one can pull without doing damage. Several persons were tested at this operative procedure, a spring balance being used. It was found that at the extreme

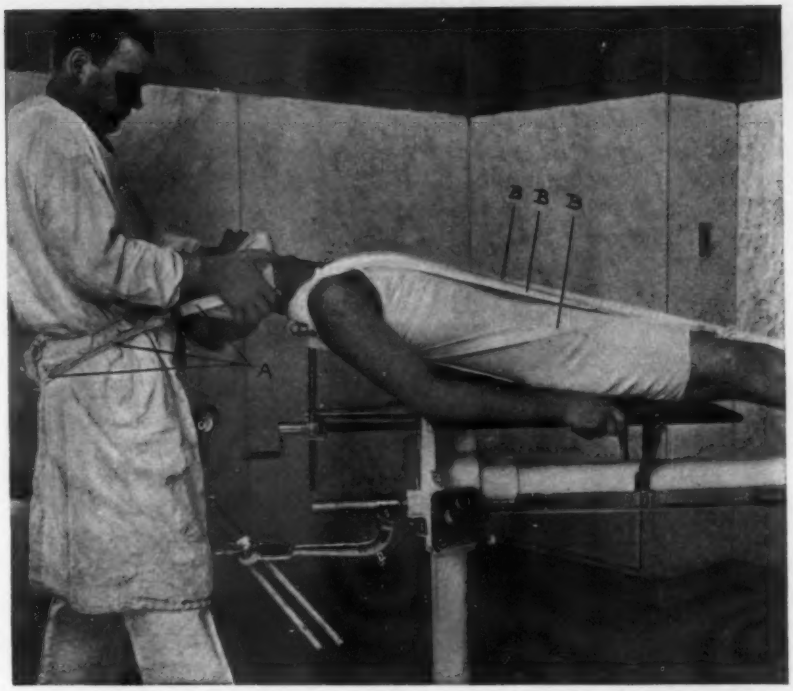

Fig. 10.—Method of applying a straight line pull for bilateral cervical dislocation. *A* indicates the halter purchase on the occiput and the chin. Note the band extending around the buttocks of the operator. *B, B, B* indicate countertraction bands that lash the shoulders to the perineal post. The operator's foot abuts against a stationary object on the floor for better purchase.

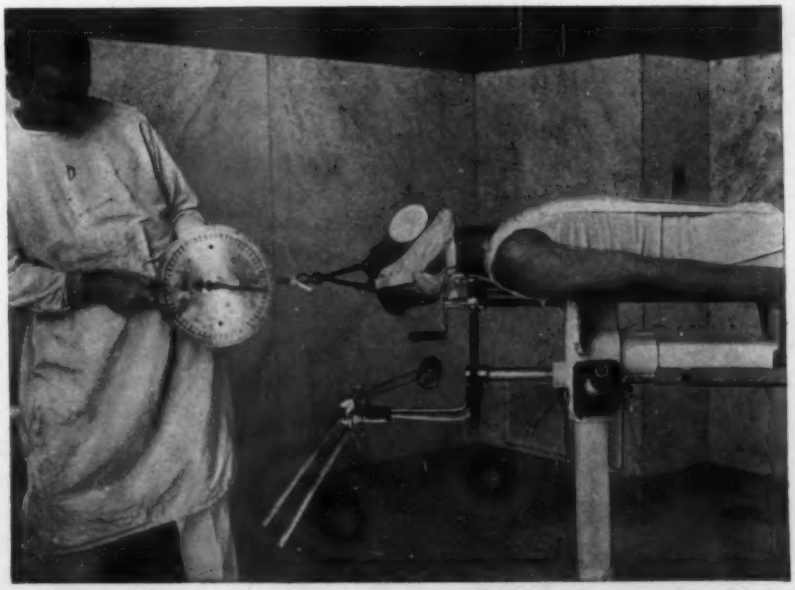

Fig. 11.—Interposed balance in the line of traction to find the traction strength of the operator in pounds. If this pull is done against the end of the table as a preliminary and the operator pulls to his utmost, the safety factor may be determined in advance.

of effort, the balance registered 80 to 125 pounds (36 to 56.5 Kg.) (fig. 11). Since the breaking point of the anterior longitudinal ligament is at weakest 160 pounds (72.5 Kg.) and the average breaking point is 337 pounds (153 Kg.), it is obvious that pulling the utmost in the standing position as illustrated will not tear the ligament or otherwise disrupt the cord or the nerve roots, provided the traction is in a straight line involving no flexion, extension or lateral deviation. Likewise, I have seen large amounts of weight used in connection with the Crutchfield tongs without damage. As much as 45 pounds (20.5 Kg.) has been applied to the skull continuously for days on end without discomfort to the patient. It is clear, however, that such a large amount of weight cannot be expected to serve a useful purpose because of the unyielding nature of the ligament. The anterior longitudinal ligament is completely inelastic. Determinations of stretch were made at the same time that the breaking point was determined. These tests were conducted in the same manner as in testing steel. During the increase in strain induced by the testing machine, the distance between two points, one above and one below a vertebral body was measured at increases of 50 pounds (22.5 Kg.) up to 150 pounds (68 Kg.) of weight imposed; no increase of separation was noted. These determinations of stretch seem completely critical since if there had been elastic yield in the ligament, pulling in the longitudinal axis or in hyperextension would carry the penalty of damage of the roots.

CERVICAL LUXATION

The analysis and manner of recognition and the treatment of a hitherto unrecorded but regularly occurring entity are herewith described. It is apparent from the histories of a number of patients that they suffered a severe injury, such as an automobile whip lash, usually some time prior to their first visit to a physician, with painful symptoms referable to the cervical portion of the spinal column. Roentgenograms of the involved regions fail to show definite evidence of forward dislocation of the body of a cervical vertebra.

There may be just sufficient luxation forward to suggest the possibility of slight displacement of the magnitude of a sixteenth of an inch or more as one looks at the anterior line of the body of the vertebra. The significant observation, however, in regard to the lateral picture is that the cervical portion of the spinal column has lost its normal anterior curve, and there usually is the slightest suggestion of anterior angulation at the level of an intervertebral space (fig. 12). It is well known that vertebrae have been completely dislocated in the cervical region, sufficiently to sever the cord, and reduced spontaneously by the patient's involuntary extensor recoil. It is assumed in these cases that a sufficient forward throw has occurred to sever the ligaments surrounding the posterior articular processes, that spontaneous replacement took place with the recoil but that the tear in the ligaments did not repair itself in the short position because no treatment was instituted. Subsequently, because of the incomplete repair of the ligamentous tear, the vertebra, under the weight of the head, gradually undergoes luxation forward. While the diagnosis and the proofs in such cases are not conclusive, it is safe to assume that the dislocation outlined has occurred and that immediate recognition of it and splintage with a collar to the hyperextended cervical portion of the spinal column are imperative to prevent gradually increasing luxation forward, which in a period of years would be sufficient to cause pain in the roots and traumatic arthritis in the intervertebral joints requiring eventual fusion to eliminate the painful disability. Several persons with a complaint of the latter kind have been seen years afterward, all of whom gave a definite history

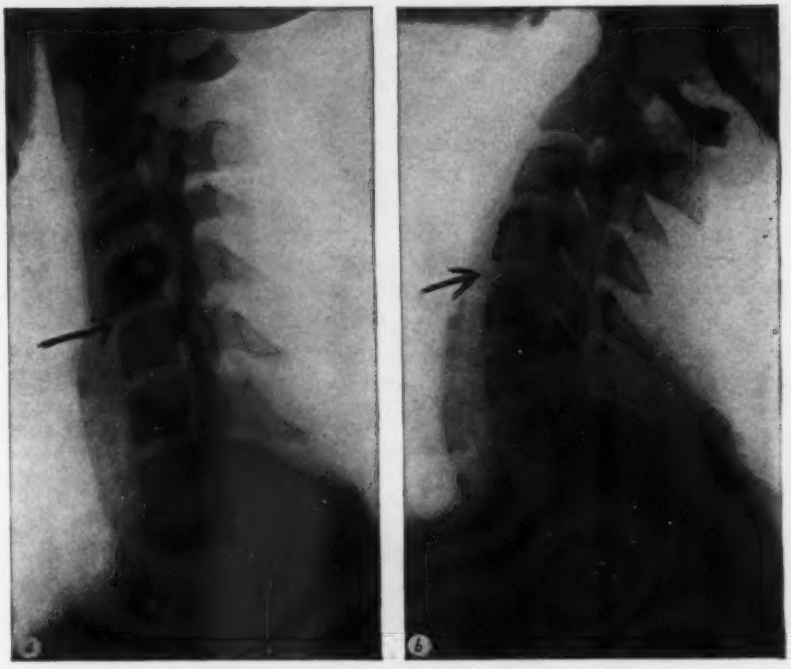

Fig. 12 (case M. M.).—(*a*) Typical partial dislocation of the cervical part of the spinal column. An arrow points to a slight forward displacement of the body of the fourth vertebra. Note the elimination of the normal cervical forward curvature. (*b*) Schanz collar in place. The normal symmetric cervical curve is exaggerated (hyperextended). The discrepancy at the fourth intervertebral space has been eliminated.

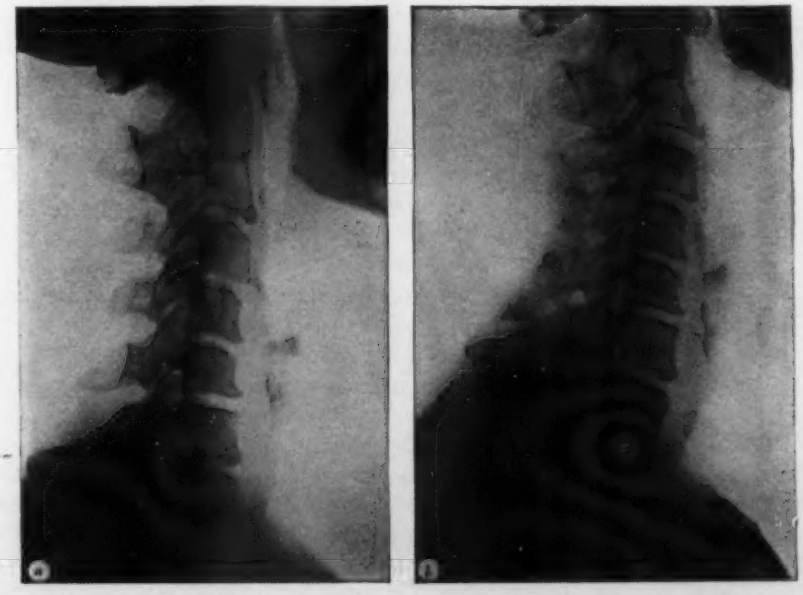

Fig. 13 (case J. K.).—(*a*) Long-standing partial forward dislocation of the third on the fourth cervical vertebra. Note the elimination of the normal cervical forward curve. (*b*) Post-operative fusion. The third, fourth and fifth vertebrae are fused to eliminate painful disability.

of a severe accident but whose symptoms at the beginning apparently did not merit roentgenographic investigation.

A case in point is that of a luxated cervical vertebra of several years' duration which was fused recently, with complete disappearance of pain due to spinal root pressure (fig. 13).

A sufficient number of these cases have not yet been reported to enable one to arrive at definite conclusions. Enough, however, have occurred so that any case presenting a history of a recent or even somewhat remote severe accident, particularly of the automobile type, and a complaint of pain in the neck should never escape roentgenographic investigation. If the lateral plate shows elimination of the cervical forward curve, this alone constitutes an anatomic change which not only requires explanation but is best explained by the mechanism described. If the patient comes for examination early, he is immediately fitted with a hyperextension collar not only restoring but exaggerating the normal anterior curvature for the time being. Such patients recover completely without operation. The collar obviously must be worn for several weeks to months.

Since this observation was made several years ago, such cases of progressive cervical luxation have become considerably more numerous. It therefore can definitely be said that this type of lesion is a clinical entity. This demonstration also points to the necessity of awareness on the part of members of the medical profession generally that all cervical injuries must be analyzed roentgenographically and of becoming accustomed to diagnosing by inference, starting with the fact that there normally is an anterior curvature of the cervical part of the spinal column and arriving at the almost inescapable conclusion that rupture of the posterior ligamentous investiture has taken place and that, the posterior ligaments having once given way, normal unguarded movements of the head will induce a progressive lesion which will later become manifest as a dislocation easily recognizable in the roentgenogram. By this time painful symptoms have so increased that fusion of two to four of the cervical vertebrae is necessary to eliminate pain.

OSTEOCHONDRITIS DISSECANS

A DISCUSSION OF TWO SIMILAR LESIONS

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Osteochondritis dissecans is an aseptic necrosis of subchondral bone and the overlying cartilage. This lesion is seen most frequently in young men. The most common site affected is the knee joint, with involvement of the medial femoral condyle and occasionally of the patella. The elbow is a frequent site, with the capitellum the most common area involved.

Trauma is considered the inciting cause for the development of this condition. Some consider that there may be a developmental or congenital background.

A condition noted in older persons resembles this lesion in some respects. It also has been described by some writers as osteochondritis dissecans. I have noted it on the medial femoral condyle in adults who required surgical treatment for a fracture of the internal meniscus. I have noted its occurrence also among persons who showed an acutely painful knee after injury to a knee joint revealing mild hypertrophic arthritis. I have also seen it involving the patella in patients who had an old injury to the patella. The lesion macroscopically consists of an erosion and fibrillation of the articular cartilage, with eburnation of the subchondral bone. Specimens taken from these areas reveal degenerated cartilage and avascular subchondral bone. Sometimes the cartilage is found to have broken loose into the joint. These fragments show, on microscopic examination, subchondral bone attached to fibrillated cartilage. In no instance have I seen this condition associated with osteochondromatosis.

The diagnosis of osteochondritis dissecans is partially dependent on an accurate roentgen examination. This is frequently found to be even more helpful than the clinical findings in making a positive diagnosis. The clinical aspects of osteochondritis dissecans can be rarely differentiated from those of a rupture of the internal meniscus when the lesion occurs in the knee. When it occurs in other joints, the diagnosis may be easier. I wish to point out the importance of careful roentgen examination as a most valuable aid in the correct diagnosis of osteochondritis dissecans. In the case illustrated by figure 1 the condition occurred bilaterally in the knees. The patient presented symptoms referable only to one joint. He was 23 years old, and could give no history of an injury to the supposedly normal knee. The symptomatic knee had been injured one year prior to the taking of these roentgenograms. At that time he had severely twisted it while at work. Following this injury, he had had constant complaints, with locking and swelling, associated with pain, as the most persistent symptoms. The presence of a similar condition in the opposite knee, without separation of the fragments, suggests that this lesion may be due to developmental changes or may have a congenital background. The roentgenograms of the other 2 cases (figs. 2 and 3) demonstrate the visualization of osteochondritis dissecans involving an ankle and the head of a femur without detachment of the fragments. Figure 2 reveals osteochondritis dissecans of an astragalus, which was first seen after the patient had suffered a severe sprain of the ankle. Figure 3 shows a similar lesion occurring in the head of a femur. The condition was first noted about a year after the patient had

received a fracture of the acetabulum, directly above the lesion in the head of the femur. Roentgenograms taken at the time of the fracture revealed no evidence of the osteochondritis dissecans.

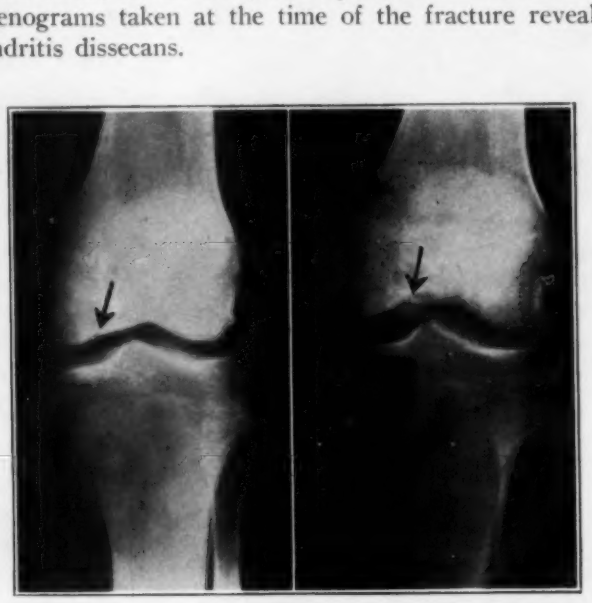

Fig. 1.—Osteochondritis dissecans of both knees of a patient who experienced symptoms from only one knee joint, for which he gave a history of injury.

Fig. 2.—Osteochondritis dissecans of the astragalus.

These 3 cases are instances of a lesion involving the articular cartilage and the subchondral bone. Trauma seems to be at least one of the etiologic factors. Whether the condition noted in the supposedly uninjured knee of the case illustrated by figure 1 was the result of unrecognized trauma is not known. Whether the changes noted in conjunction with other injuries to joints, as in the case in

which the patient revealed fibrillating cartilage of the medial condyle of the femur with underlying eburnation of the subchondral bone associated with a fractured internal meniscus, are properly classified under this title is not clear. The underlying factors seem to be the same, namely, aseptic necrosis with involvement of cartilage and subchondral bone. The clinical picture is not the same in most instances. Locking is not a common complaint in cases of the latter type, and the diagnosis is usually clouded by the complaints associated with the primary condition requiring care. The name "osteochondritis dissecans" fits the charac-

Fig. 3.—Osteochondritis dissecans occurring in the head of a femur.

teristics in both lesions. However, the other lesions described seem to fit more accurately into the category of lesions associated with hypertrophic arthritis and may well be described as degenerative osteochondritis dissecans. They are not as well walled off and circumscribed in character as those visualized in the roentgenograms and are most commonly associated with some primary change in the joint. The roentgenographic changes are quite different.

As to treatment of the two types of lesions described under this title, my associates and I have found that the therapy for degenerative osteochondritis dissecans is identical with that for true osteochondritis dissecans. In both instances

the articular surface has to be thoroughly smoothed off, the loose fragments taken out and the overhanging shelves removed. The response to this type of treatment in the one condition is also very similar to the response in the other. The relief of pain and discomfort in both instances is quite apparent.

In discussing osteochondritis dissecans I have given as examples 3 classic cases, in one of which the disease was bilateral. The importance of accurate roentgen examination in making a correct diagnosis cannot be overemphasized. I have pointed out the similarity of this lesion to the frequently noted lesion involving the internal condyle of the femur and the patella in patients who have required surgical treatment for fracture of the internal meniscus, old injury of the patella and hypertrophic arthritis. I have preferred to classify lesions of the latter type under the title of degenerative osteochondritis dissecans. The differential findings between these similar types, as well as the common findings, have been discussed in order to reveal more clearly why I consider these two types of osteochondritis dissecans as representing similar responses to different etiologic factors.

9 Buttles Avenue.

PSEUDARTHROSIS AND NEUROFIBROMATOSIS

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AND
LIEUTENANT (JG) NATHAN RUDO (MC), U.S.N.

Although pseudarthrosis has been described in association with neurofibromatosis, the mechanism by which it arises has not been explained.[1] It is our purpose to report a case of congenital bow leg and pseudarthrosis of the tibia and the fibula associated with neurofibromatosis in which studies have assisted in clarifying the genesis of pseudarthrosis and localized lesions of bone in this condition. The history, the surgical treatment and the pathologic observations are reported in detail.

REPORT OF A CASE

I. D., a girl aged 6 years 11 months, was admitted to the Children's Hospital on May 14, 1940, complaining of a tender swelling in the right arm and a deformity of the right leg. A lump in the right arm was noted eight months prior to admission. It had increased slightly in size since the original observation, and although it did not interfere with the use of the arm, it was quite sensitive to pressure.

The bowing of the right leg had been present since birth and, except for the deformity, had caused no symptoms. The mother was of the opinion that the degree of deformity had not changed over the years. There was no history of trauma, and at no time had there been any complaint of discomfort. The other details of the history obtained were not considered pertinent to this presentation except that the father had small café au lait spots on his skin.

Physical Examination.—The child was rather undersized and undernourished. Her skin showed multiple areas of brownish pigmentation, so-called café au lait spots (fig. 1). Her head was markedly dolichocephalic in type and her jaw was prognathic. Her posture was poor, with increased lordosis, protruding abdomen and round shoulders. There was no beading of the ribs or Harrison's groove. Otherwise the examination was not significant except for findings in the right arm and the right lower extremity.

Palpation of the lateral aspect of the right arm at the juncture of the lower and the middle third revealed a tender firm nodular mass beneath the subcutaneous tissue, the main portion of which was about 3 cm. long and 0.6 cm. in diameter.

The right leg showed increased knock knee with anterolateral bowing of the tibia. The left leg was entirely normal, and the lower extremities were equal in length.

Roentgenograms of the right leg taken at the time of admission (fig. 2) revealed an ununited oblique fracture in the distal portion of the fibula, which had evidently been present for some time, and a sinuous bowing of the tibia, most marked in an anterolateral direction. The tibia showed an irregular thickening of the cortex, which was maximal at the level of bowing, but no localized defects could be seen in the bone at this time. Roentgenograms of the remainder of the skeleton showed no significant abnormalities. However, a review of

From the departments of orthopedic surgery and pathology of the Children's Hospital and the Harvard Medical School.

1. (*a*) Stalmann, A.: Nerven-, Haut- und Knochenveränderungen bei der Neurofibromatosis Recklinghausen und ihre entstehungsgeschichtlichen Zusammenhänge, Virchows Arch. f. path. Anat. **289**:96, 1933. (*b*) Ducroquet, R.: A propos des pseudarthroses et inflexions congenitales du tibia, Mém. Acad. de chir. **63**:863, 1937. (*c*) Ducroquet, R., and Cottard, A.: Pseudarthrose congenitale de jambe. Deformation osseuse de la neurofibromatose, J. de chir. **53**:483, 1939. (*d*) Barber, C. G.: Congenital Bowing and Pseudarthrosis of the Lower Leg: Manifestations of von Recklinghausen's Neurofibromatosis, Surg., Gynec. & Obst. **69**:618, 1939. (*e*) Moore, B. H.: Some Orthopaedic Relationships of Neurofibromatosis, J. Bone & Joint Surg. **23**:109, 1941.

roentgenograms which had been made elsewhere two years previously revealed that the fracture of the fibula was not present then, although the appearance of the tibia and the fibula was otherwise similar to that seen in the more recent films.

Laboratory examinations on admission showed no particular abnormalities. The values of blood calcium and phosphorus were 9.9 mg. and 5 mg. per hundred centimeters, and the value of phosphatase was 9.3 Bodansky units. An intradermal test with tuberculin in the dilution of 1:1,000 was negative, as was the Hinton test for syphilis. The blood cell counts were normal, as were the findings in the urine.

First Operative Procedure.—On May 27 the mass in the right arm was exposed and found to be a wormlike nodular whitish tumor, which was attached to the radial nerve and in part had to be dissected from it. There were many continuations from the main mass into

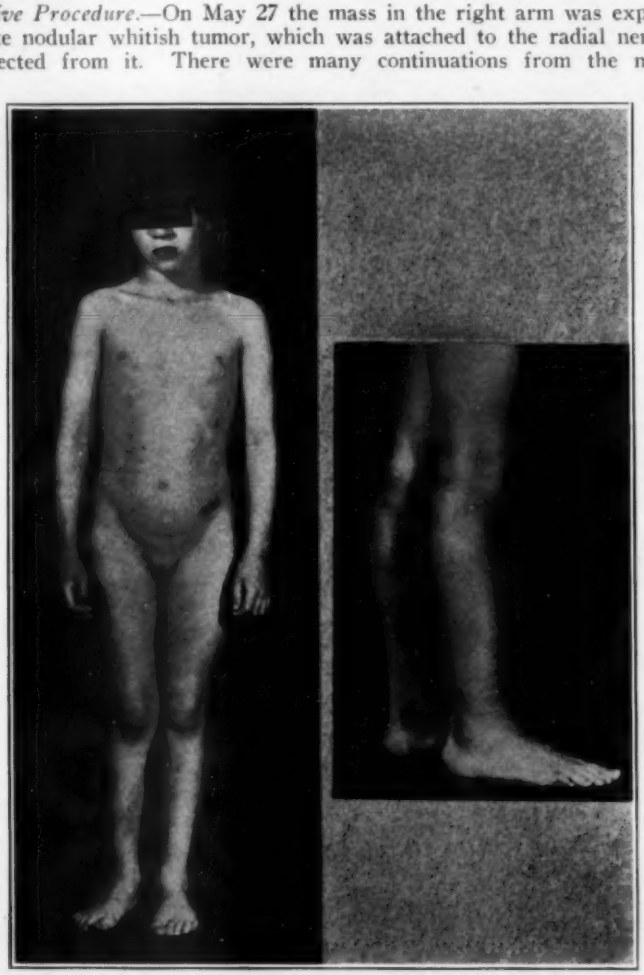

Fig. 1.—Photographs taken in May 1940 when the patient was first admitted to the Children's Hospital, at the age of 7 years. Note the pigmented patches on the trunk and the anterolateral bowing of the right leg.

the fascia and muscles, although bone and periosteum were not involved. All recognizable tumor tissue was excised.

An incision was then made over the distal third of the right leg so as to expose the tibia at the site of maximal cortical thickening and the fibula in the area of the defect which was visible in the roentgenograms. About 5 cm. above the lateral malleolus, the periosteum over the fibula was found thickened and the underlying bone was bulbous. Incision of the periosteum exposed a definite area of nonunion, from which a rectangular block of bone was removed so as to give a representative longitudinal section of the area. Following this, a section of bone for microscopic examination was removed from the tibia at the site of the greatest cortical thickening. The leg was immobilized in a plaster splint from the toes to the groin, with the knee flexed at about 45 degrees.

Pathologic Examination of the Tissues Obtained at the First Operation.—The material excised from the right arm was a serpentine mass of thickened nerves. Microscopic examination showed the nerve bundles to be thickened by a proliferation of loosely arranged elongated spindle-shaped cells, a picture typical of plexiform neuroma (fig. 3).

The block of bone and attached periosteum removed from the region of the ununited fracture of the fibula displayed a freely movable line of dense soft tissue 2 to 3 mm. wide. This zone corresponded to the fracture line seen in the roentgenograms.

On microscopic examination the fracture fragments were seen to be separated by a vascular cellular tissue composed of streaming bundles of elongated cells with little or no intervening collagen. The nuclei in some areas showed a tendency to form parallel rows or "palisades" (figs. 4 and 5). Osteoblastic activity and osteoid formation were evident along the margins of the fracture fragments, and in this region there was an intermingling of the described cellular tissue with fibrous and osteoid tissues. This intermingling of the soft cellular tissue with the osteoid material produced a defective type of osteoid, poorly calcified.

Fig. 2.—Roentgenograms of the right leg in the anteroposterior and lateral views taken at the time of the first admission, May 14, 1940, show the anterior and lateral bowing of the tibia, with thickening of the cortex, and the ununited fracture of the fibula.

There were areas of a more cartilaginous type of callus in which there was a tendency for the tissues to disintegrate with formation of eosinophilic debris. In these areas osteoclastic giant cells were numerous.

The bone at a little distance from the fracture line was entirely normal. The periosteum did not contain any cellular tissue of the type that was found between the fracture fragments. The pathologic diagnosis was intraosseous neurofibroma of the fibula with pathologic fracture and pseudarthrosis.

The specimen taken from the right tibia was found on microscopic examination to consist of cortical bone which was not unusual except for slight enlargement of the haversian canals. The connective tissue within the canals was quite vascular and showed no neoplastic change or other abnormality. The overlying periosteum was not abnormal. The diagnosis was cortical thickening of the tibia with enlarged haversian canals.

Course in the Interval Before the Second Admission.—When the splint which had been applied at the first operation was removed, Sept. 5, 1940, fourteen and one-half weeks after the operation, there was still no roentgenographic evidence of union of the fibula, although the defect in the tibia created by the removal of the block for microscopic examination had healed.

Roentgenograms taken on September 19 showed a new rounded defect in the tibia, distal to the site of the previous removal of a section of bone and opposite the site of nonunion in the fibula (fig. 6). This was interpreted as probably a neurofibroma of bone. It was decided that no intervention should be made at this time, but that the defect should be observed.

Second Admission to the Hospital.—On December 14, seven months after the previous admission to the hospital, the patient was readmitted, with the story that eight days before,

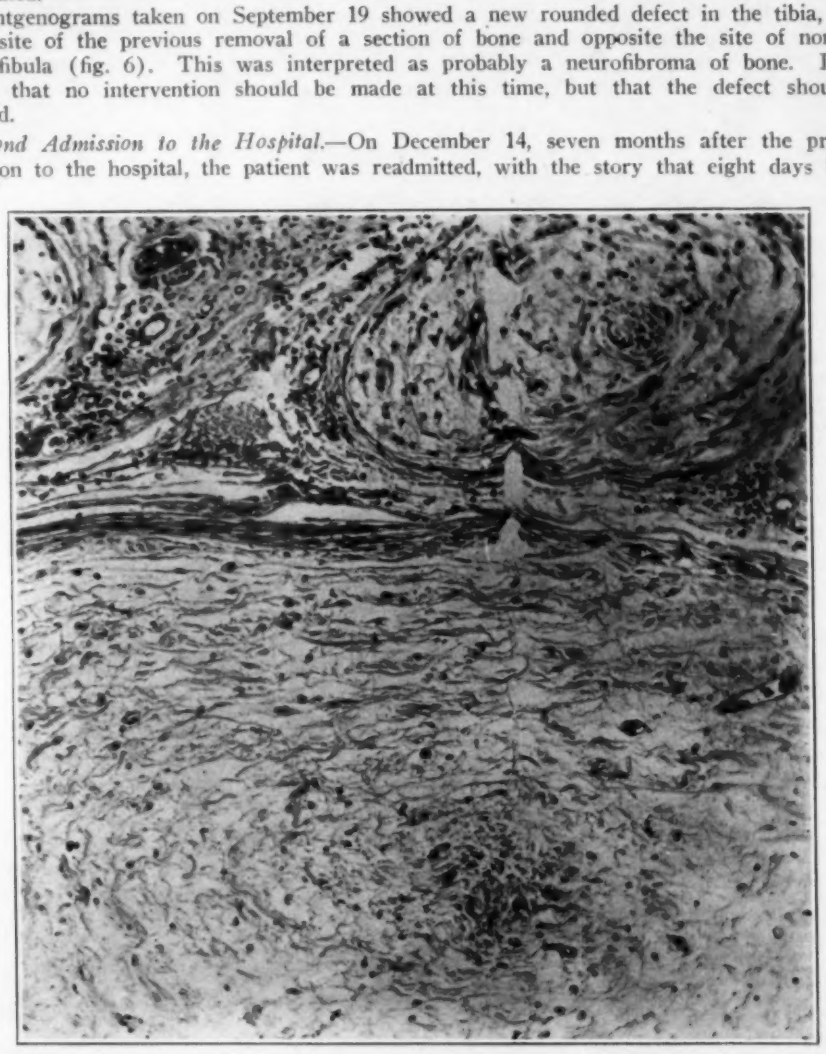

Fig. 3.—Photomicrograph (× 120) of a section of the plexiform neuroma removed from the right arm. Two small nerve bundles and a part of a larger one are shown enlarged by the proliferation of loosely arranged neurofibroma tissue. Nuclear palisading is slight. Nerve fibers persist in the centers of the bundles.

while playing in the snow, she fell and injured her right leg. She was taken to a nearby hospital, where an unsuccessful attempt was made to reduce a fracture of the right tibia and fibula. She was then transferred to this hospital with her leg immobilized in a plaster splint. Roentgenographic examination showed a transverse fracture of the tibia at the juncture of the distal two thirds and proximal one third, with a new fracture of the fibula at this same level (fig. 7). The tibia had been fractured approximately through the area of previous removal of bone for biopsy, although no gross defect from this procedure was visible in the roentgenograms. The line of fracture did not involve the defect in the tibia which had been recognized at the last roentgenographic examination and interpreted as a neurofibroma of bone. Attempts

at closed reduction of this fracture were unsuccessful in that, although the fracture could be reduced, the surfaces seemed to be smooth and could not be locked in position.

Second Operation.—Open reduction of the fracture with biopsy of the defect of the tibia was performed on December 23. There seemed to be a small amount of fresh subperiosteal callus at the site of fracture and some similar tissue between the fragments. This was resected down to healthy-appearing bone, and the fracture was fixed with a four screw vitallium plate. Following this, the defect in the tibia distal to the fracture was exposed. The tissue in this area in its gross aspect resembled granulation tissue in many particulars and was separated from the periosteum by a thin layer of cortical bone. It was resected for histologic examination.

Pathologic Examination of Tissues Obtained at the Second Operation.—The soft tissue nodule removed at the site of the roentgenographic defect and the material from the site of

Fig. 4.—Photomicrograph (× 81) of a section taken through the ununited fracture of the fibula. A broad central zone of vascular tissue lies between the adjacent fracture ends. Numerous thin-walled blood channels are present. Osteoclastic type giant cells are seen at the upper right; osteoblastic activity and osteoid formation are seen at the upper center and lower right.

nonunion both showed a histologic picture entirely similar to that seen in the tissue from the area of nonunion in the fibula previously described (fig. 8 *A* and *B*). The diagnosis was (1) neurofibroma of bone and (2) pathologic fracture of the tibia with neurofibroma of bone.

Course in the Interval Before the Third Admission.—The extremity was immobilized in a plaster splint, which was not removed until April 9, 1941, approximately three and one-half months after the operation. At this time union was solid and there was definite callus with obliteration of the fracture line.

Third Admission to the Hospital.—This girl was again admitted on June 5, 1941 with the story that ten days before this she had stumbled over a cobblestone, with immediate

pain in her right leg. The trauma was minimal. She was able to walk, but the leg became swollen and painful.

Examination showed tenderness in the distal portion of the tibia, below the site of the former fracture. Roentgenographic examination showed a transverse fracture of the tibia, distal to the previous fracture, at the site of the most recent removal of tissue for biopsy, although the defect created at that time had almost completely healed (fig. 9). There were, however, a few new defects anteriorly just below the fracture line. There was no displacement, and the extremity was immobilized in a plaster splint for seven weeks. Since at the end of this time there was no evidence of union, and definite defects in the bone adjacent to the line of fracture existed, an open procedure was performed.

Third Operation.—On July 29 an incision was made in a longitudinal direction over the distal third of the tibia, excising the scar of the previous operation in this area. The vitallium plate which was used in the immobilization of the previous fracture was removed. Union was solid in this area, and no abnormal tissue was noted. The site of the recent fracture

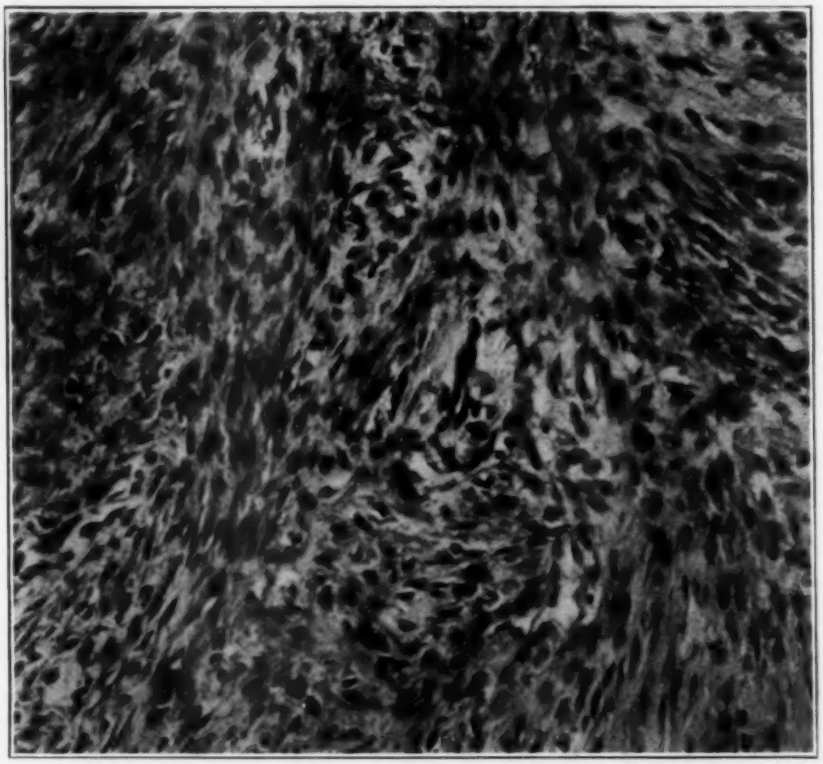

Fig. 5.—A higher power photomicrograph (× 250) of the tissue in figure 4. The streaming, swirling, interlacing bundles cut in various planes and the nuclear palisading are characteristic of neurofibroma.

was then exposed. There was no evidence of union. The bone adjacent to the line of fracture in the tibia was resected, as was the area of nonunion in the fibula. The resected portion of the tibia contained certain defects occupied by tissue of fibrous type. The surfaces of the tibia were coapted and plated in position. The distal fragment of the tibia was very atrophic and friable. The use of a large bone graft was considered, but deferred at this time; small osteoperiosteal grafts were placed across the line of fracture. The extremity was immobilized by means of a circular plaster splint extending from the toes to the groin.

Pathologic Examination of the Tissue Removed at the Third Operation.—The tissue was similar to that seen in previous sections. The histopathologic diagnosis was recurrent neurofibroma of bone with pathologic fracture.

Fourth Admission to the Hospital.—Roentgenograms of December 15 (fig. 10 *A* showed the bone plate to be holding the fragments in good position, but there was no evidence of

union; in fact, there was absorption of bone from the adjacent surfaces. The patient was then allowed partial weight bearing, a modified Boehler walking iron being used. The absorption of bone from the adjacent fragments which was in evidence in the roentgenograms of December 15 increased markedly, and the patient was readmitted to the hospital on May 16, 1942. The roentgen picture at this time was typical of pseudarthrosis of the tibia.

Fourth Operation.—On June 25 the vitallium plate, which had broken, was removed, the tissue occupying the fracture line, which was of gray glistening character, was widely excised, and two large bone grafts removed from the opposite tibia were inserted in onlay fashion with fixation by vitallium screws after the technic used by Boyd.[2]

Pathologic Examination of the Tissue Removed at the Fourth Operation.—Again, histologic examination of tissue from the site of nonunion led to the diagnosis of recurrent neurofibroma of bone.

On October 15 roentgenograms of the tibia showed solid union (fig. 10 *B*).

Fig. 6.—Roentgenograms, oblique and lateral views, made on Sept. 19, 1940, sixteen weeks after the first operative procedure. The fracture of the fibula is still ununited, although a small amount of callus has formed. The biopsy defect in the tibia is almost obliterated, although the bone in this region is more dense. The small rounded defect in the tibia is seen for the first time. Note its position well below the site of the removal of bone for biopsy.

COMMENT

The case under consideration presented bowing and pathologic fractures of the tibia, as well as pseudarthrosis of the fibula, in association with neurofibromatosis. The extraosseous manifestations of the neurofibromatosis included numerous café au lait spots on the skin and a plexiform neuroma involving the radial nerve.

Although pseudarthrosis has been noted as associated with neurofibromatosis in certain instances, the actual mechanism by which it occurs has not been demon-

2. Boyd, H. B.: Congenital Pseudarthrosis: Treatment by Dual Bone Grafts, J. Bone & Joint Surg. **23**:497, 1941.

strated. Moore [1e] stated: "We believe that the condition of the nerve and the pseudarthrosis stand in the relationship of cause and effect, though the mechanism of the production is not clear." In none of the reported cases of pseudarthrosis associated with generalized neurofibromatosis have we been able to find a microscopic description of the tissue from the area of pseudarthrosis.

In our case the pseudarthrosis seems to be associated directly with intraosseous neurofibromas which caused pathologic fractures of the tibia and the fibula and retarded or prevented bony union. The rounded defect in the tibia is interpreted as an example of the first step in the process, that is, the development of a neurofibroma within the bone (fig. 6). The evidence suggests that the ununited fracture of the lower end of the fibula had been preceded by the formation of a similar defect. This

Fig. 7.—Anteroposterior and lateral views of the leg in a plaster splint, made Dec. 14, 1940, when the patient was readmitted to the hospital. There is a rather smooth transverse fracture of the tibia at the level of the site of removal of the biopsy specimen. Just below this level there is a new fracture of the fibula. The old fracture of the fibula remains ununited. The rounded defect in the tibia, noted previously (fig. 6), is somewhat larger.

fracture was caused by trauma so slight as to escape the notice of the patient. The failure of the fibula to unite was due to the presence of neurofibromatous tissue between the fracture fragments.

The first fracture of the tibia occurred in an area where tissue had been removed for biopsy. Exploration of this fracture seventeen days after its occurrence demonstrated the presence of neurofibroma between the bone ends. After excision of this tissue with open reduction of the fracture and immobilization by internal fixation, this fracture united satisfactorily.

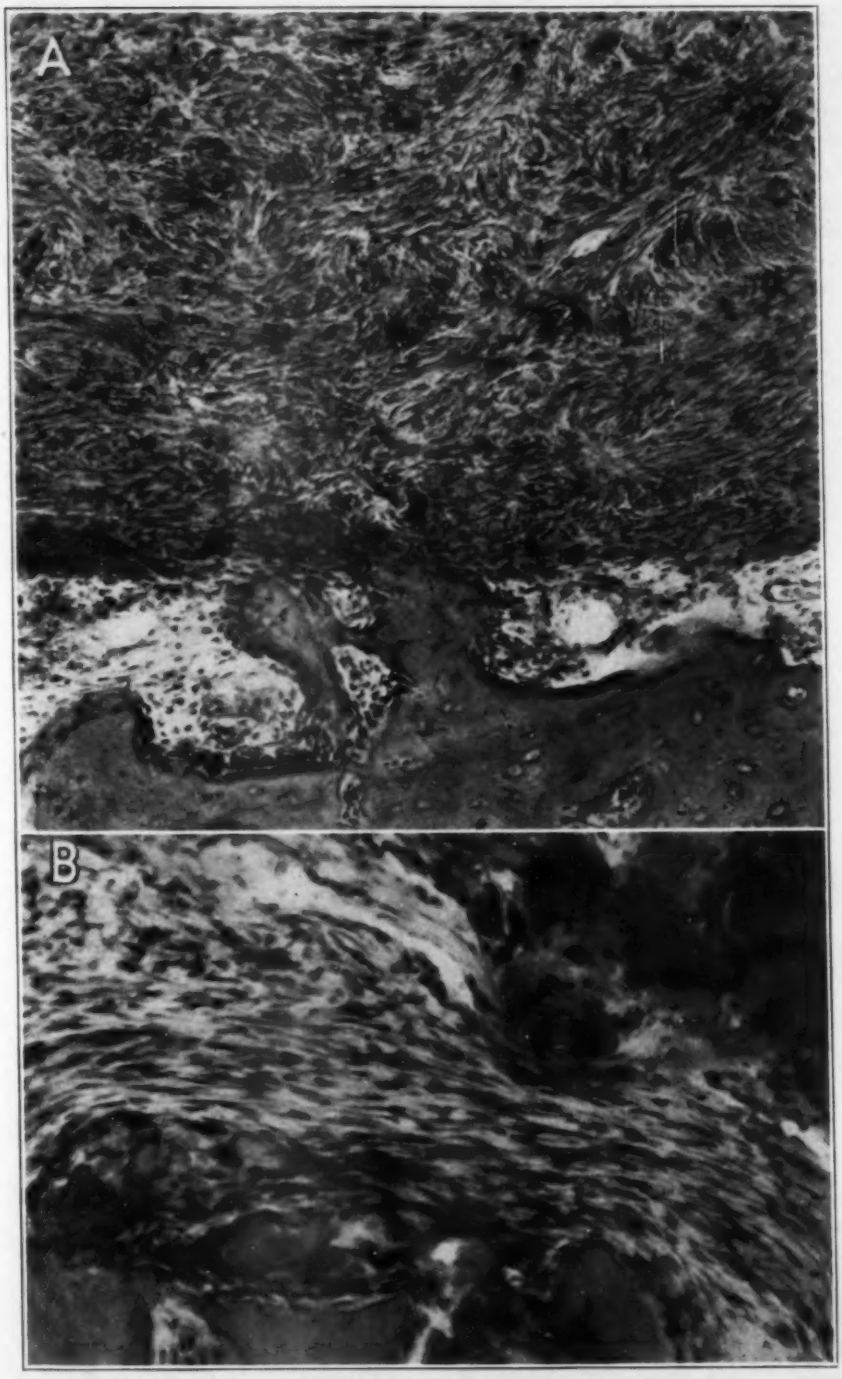

Fig. 8.—*A*, photomicrograph (× 170) of a section made through the soft tissue nodule occupying the small rounded defect in the tibia (fig. 6). The tissue is similar to that found in the area of pseudarthrosis of the fibula (fig. 5). Note the distinction between the tumor tissue and the adjacent intertrabecular connective tissue. The surrounding bone shows osteoblastic activity and the formation of normal new bone tissue. *B*, photomicrograph (× 250) of tissue obtained from the margin of the first fracture of the tibia, seventeen days after the fracture occurred. A streaming bundle of neurofibroma tissue occupies the site of fracture.

The second fracture of the tibia occurred in an area where neurofibromatous tissue had been demonstrated histologically prior to the fracture. This fracture, as all the others, occurred with little trauma and is attributed to the persistence and growth of the neurofibroma which had been incompletely excised at the time of the biopsy in this area. New defects in the bone at this level were demonstrable roentgenologically and at operation, when the second open reduction with plating was done.

This fracture failed to unite; there was increasing absorption of bone with fracture of the bone plate. The roentgen picture at this time was entirely typical of so-called pseudarthrosis of the tibia.

Fig. 9.—Anteroposterior and lateral views taken June 5, 1941, ten days after mild trauma. A new transverse fracture of the tibia is seen distal to the bone plate and at the site of the biopsy specimen of Dec. 23, 1940. The defect created by the operation is almost obliterated, but new defects are seen anteriorly just below the line of fracture. The fractures of December 1940 have healed.

Again exploration demonstrated the presence of recurrent neurofibroma. This was widely excised and fixation was secured by means of dual bone grafts (Boyd), with union following.

The tissue removed from the area of pseudarthrosis of the fibula and from the regions of pathologic fracture of the tibia was in many areas indistinguishable microscopically from that obtained at the biopsy of the localized osseous lesion which was unassociated with fracture. All showed a similar structure, consisting of streaming, swirling, interlacing bundles of elongated cells, with the nuclei tending to aline themselves in rows or "palisades." Only a scant amount of collagen was distributed

between the cells and between the cell bundles. In the areas of fracture the adjacent bone showed definite ability to produce osteoid tissue, but the neurofibromatous tissue became intermingled and incorporated with it, resulting in a poorly calcified and defective type of osteoid tissue.

It was suggested in our case that the intraosseous neurofibromas developed from nerves within the bone rather than from those of the periosteum. The periosteum was singularly free of tumor tissue except in a single portion and that was the site of a recurrence of the tumor after a biopsy had been done in the area.

Fig. 10.—*A*, roentgenogram of Dec. 15, 1941, four and one-half months after the plating of the second fracture of the tibia shows absorption of bone from adjacent surfaces, with no evidence of union. *B*, roentgenogram of Oct. 15, 1942, taken approximately four months after dual bone grafts, shows healing of pseudarthrosis.

Even the localized tumor defect of the tibia (fig. 6), which the roentgenograms indicated was immediately beneath the periosteum, was found at operation to be separated from the latter by a small shell of cortical bone. This would suggest that the neurofibromatosis arose in intraosseous nerve tissue. That nerve tissue exists within the bone has been demonstrated by Stohr [3] and others. It is possible

3. Stohr, P.: Das peripherische Wervensystem, in von Möllendorff, W.: Handbuch der mikroskopischen Anatomie der Menschen, Berlin, Julius Springer, 1928, vol. 4, p. 419.

however, as proposed by Brooks and Lehman,[4] that the neurofibromas may arise from the nerves of the periosteum, erode into the bone and subsequently be covered by a shell of bone laid down by the periosteum, although this was not suggested by the findings in our case.

The cause of the bowing of the tibia is not readily apparent. We have seen several other patients with bowing of a similar character in association with neurofibromatosis. The discovery of tumor tissue in the shaft of the bone might lead one to speculate as to the possibility of the presence of neurofibroma at the zone of enchondral ossification, causing inequality of the rate of bone growth and consequent deformity. Under such circumstances, with progression of the growth zone away from the tumor, the normal rate of growth might be reestablished. No evidence to support this theory could be determined, as roentgenographically no definite defects in the tibia were demonstrated before the child was admitted to the hospital at the age of 7 years.

The findings in this case have led us to review the literature of "congenital pseudarthrosis," and although there is considerable speculation on the nature of the process, actual pathologic investigation has been relatively meager. In some instances of this condition "cysts" of the bone have been reported to have been demonstrated by roentgenograms prior to the occurrence of the fracture which led to the pseudarthrosis. These cases have been considered from the roentgenographic evidence as instances of a congenital form of localized osteitis fibrosa cystica.[5]

Wade[6] reported several cases of congenital pseudarthrosis of the tibia, in some of which there was also bowing of the bone. He made no mention of neurofibromatosis as being a factor in his cases. Inglis[7] examined the material from Wade's cases and described fibrous and fibroblastic tissue between the ends of the fragments "such as might be found in a simple connective tissue new growth." In his paper he presents photomicrographs of material from 2 of his patients and describes the intimate intermingling of the "connective tissue" with the adjacent osteoid tissue in a manner which from the description seems to be similar to that found in sections from the ununited fracture of the tibia in our case. It would seem possible that the pseudarthrosis reported by him may have been due to the presence of a neurofibroma.

In this connection it should be emphasized that the differentiation of neurofibromatous tissue from fibrous and connective tissue of other origins may be most difficult in many instances. On other occasions the cellular structure and arrangement make the differentiation easier. In our case the similarity of the tissue from the area of pseudarthrosis to that of the localized tumor of the bone, which was definitely neurofibroma, assisted in the differentiation.

In cases of "congenital pseudarthrosis" search should be made for evidences of neurofibromatosis, including café au lait spots, tumors of peripheral nerves and roentgen evidence of other bony lesions. The absence of manifestations of neurofibromatosis elsewhere does not exclude the possibility of neurofibroma of the bone

4. Brooks, B., and Lehman, E. P.: The Bone Changes in Recklinghausen's Neurofibromatosis, Surg., Gynec. & Obst. **38**:587, 1924.

5. Scott, C. R.: Congenital Pseudarthrosis of the Tibia, Am. J. Roentgenol. **42**:104, 1939. Kite, J. H.: Congenital Pseudarthrosis of Tibia and Fibula, South. M. J. **34**:1021, 1941.

6. Wade, R. B.: So-Called Congenital Pseudarthrosis of the Tibia, J. Coll. Surgeons, Australasia **1**:181, 1928.

7. Inglis, K.: The Pathology of Congenital Pseudarthrosis of the Tibia, J. Coll. Surgeons, Australasia **1**:194, 1928.

as the etiologic factor in the given case, since neurofibroma of bone has been demonstrated without recognizable lesions elsewhere.[8]

The possibility that the pseudarthrosis may be due to the presence of neurofibromatous tissue should be considered at operation in all instances of "congenital pseudarthrosis." Detailed studies should be made of the tissue removed at the operative procedure to demonstrate or exclude the possibility of neurofibroma, with the realization that superficial examination may suggest the diagnosis of "scar tissue." If neurofibroma is present, incomplete excision of this tissue may lead to recurrence and thus be a factor in the failure of union.

SUMMARY

A case which presented bowing of the tibia and the fibula, pathologic fractures and pseudarthrosis associated with neurofibromatosis is reported.

Pathologic examination revealed intraosseous neurofibroma as a factor in the production of the fractures and in the retardation or prevention of union.

In cases of "congenital pseudarthrosis" the patient should be examined for stigmas of neurofibromatosis, which include café au lait spots, extraosseous tumors and roentgen evidence of other skeletal defects. In operations on patients with "congenital pseudarthrosis" the possibility that the process may be due to the presence of neurofibroma in the area should always be considered. If neurofibroma is the cause of the pseudarthrosis, incomplete excision of the tumor with local recurrence may be a factor in nonunion.

8. Desanto, D. A., and Burgess, E.: Primary and Secondary Neurilemmoma of Bone, Surg., Gynec. & Obst. **71**:454, 1940.

PAIN IN THE SHOULDER GIRDLE, ARM AND PRECORDIUM DUE TO FORAMINAL COMPRESSION OF NERVE ROOTS

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In a previous publication [1] attention was directed to a series of cases in which radicular pain radiating to the shoulder girdle, the arm and the precordium originated in the cervical portion of the spinal column and was due to arthritic changes. The symptoms and the diagnosis were discussed, and a suspension type of traction therapy was suggested. It was further suggested that overhead traction was of distinct value as a diagnostic aid. Particular attention was directed to the precordial reference of cervical radicular pain and to the necessity for differentiating this type of pain from true anginal pain.

Since this earlier publication, it has been possible to study a much larger group of cases of the condition described, and an opportunity has presented itself to study and observe many other conditions which simulate this one in the syndrome produced. It was accordingly deemed advisable to supplement the previous publication with an article emphasizing the differential diagnosis and the use of overhead traction as a diagnostic aid.

PATHOLOGY

It must be stated frankly that the mechanism of the impingement on nerve roots in these cases is still obscure. This is obviously due to the fact that it is not possible to see by direct vision the changes responsible for the impingement. Many interesting suggestions have been offered, as well as some ingenious roentgenologic investigations. The hypotheses can be best understood if one first considers briefly the anatomy of the cervical intervertebral foramen.

The foramen is bounded anteriorly by the posterior surfaces of the vertebral bodies, which are covered by the posterior longitudinal ligament. The upper and lower margins are formed by the concave borders of the pedicles of the superjacent and subjacent vertebrae. The posterior margin is the synovial membrane and ligaments of the apophysial joint.

It has been suggested by Oppenheimer [2] that the foramen may be narrowed by a breakdown of any of the tissues that normally hold in place the bones that form the foramen. Thinning of an intervertebral disk may represent such a breakdown. Whatever the cause of the thinning of the disk, it is obvious that as the space between the vertebrae diminishes, the height of the foramen diminishes. The forward displacement of the superior articular process of the subjacent vertebra which occurs must of necessity cause a similar decrease in the lateral diameter.

1. Hanflig, S. S.: Pain in the Shoulder Girdle, Arm and Precordium, J. A. M. A. **106**:523-526 (Feb. 15) 1936.

2. Oppenheimer, A.: (*a*) Diseases Affecting the Intervertebral Foramina, Radiology **28**:582-592 (May) 1937; (*b*) Narrowing of the Intervertebral Foramina as a Cause of Pseudorheumatic Pain, Ann. Surg. **106**:428-440 (Sept.) 1937.

In the cervical portion of the spinal column degenerative changes in the intervertebral disks occur most frequently from the fifth to the seventh cervical vertebrae. The fact that the nerve roots associated with these vertebrae are larger than the upper cervical nerve roots may explain the frequency of radicular symptoms originating at these levels. It has been thought that spur formations and bridgings are secondary irritative phenomena incident to the narrowing of the disks and the approximation of bony surfaces.

Oppenheimer further suggested that the foramen may be encroached on and narrowed by the formation of bony or inflammatory tissue. Into this group may fall primary apophysial arthritis with resulting thickening of synovial, ligamentous and periosteal structures. This concept may explain the manner in which a single trauma or chronic trauma due to malalinement or postural strain may produce radicular irritation. One must also think of a posterior exostosis occurring in such a location as to encroach on the foramen.

Whichever mechanism is accepted as the one producing the narrowing of the intervertebral foramen, one must conclude that it is but a predisposing factor and that there is an additional inflammatory element superimposed on it. Otherwise, one could not explain the lasting beneficial effects of traction or high voltage roentgen radiation.[3] One cannot expect traction or roentgen therapy to restore the thickness of a thinned intervertebral disk or to reduce the size of an exostosis. I take exception to a statement by Oppenheimer [2b] that "the considerable narrowing of the foramen thus caused is quite sufficient to account for marked compression of nerve roots," and that "it is unnecessary to assume, under these conditions, some additional inflammatory reaction of soft tissues—which, by the way, has never been observed at operation or autopsy." There must be an added inflammatory factor. Traction affords relief by temporarily increasing the size of the foramen and allowing the neuritis caused by friction to subside. Similarly, high voltage roentgen radiation reduces the edema and congestion of inflammatory tissue and by doing so probably increases the foraminal space.

CLINICAL PICTURE OF IMPINGEMENT ON A NERVE ROOT

Whether the cause of impingement on a nerve root is the increase in size of an exostosis, the narrowing of the foramen due to inflammatory encroachment or the thinning of an intervertebral disk, the clinical picture is always characteristic.

The symptoms are much more frequently referable to the lower cervical than to the upper cervical region of the spinal column. If the irritation is in the latter region, the pain begins in the upper posterior region of the neck and radiates up over the occiput toward the temporofrontal region. This pain is commonly referred to by the patient as a headache and is usually worse in the morning. It may be associated with a burning or an aching sensation in the occiput.

If the symptoms arise in the lower cervical region, the pain is referred to the top and back of the shoulder and the outer border of the arm. From there it may travel into the outer aspect of the forearm, the wrist or the fingers. There may be paresthesias of any of the fingers of the hand. Commonly, however, these are confined to the thumb and index fingers. The pain is often referred to the precordium and may simulate and be mistaken for anginal pain.

The type of symptoms produced is further influenced by the amount of impingement and the portion of the nerve root involved. Any portion of the nerve root, sensory, motor or even sympathetic, may be involved. Sensory are more frequent

3. Kelly, LeM. C.: Chronic Hypertrophic Osteoarthritis in the Cervical Spine with Radiculitis, New York State J. Med. **42**:336-340 (Feb. 15) 1942.

than motor changes. This may be due to the fact that the motor fibers of the anterior cervical roots are fewer than the posterior sensory fibers, comprising a bundle only one-third the size of the latter. The degree of impingement may cause variation in sensory changes, from paresthesias and numbness to severe intractable pain. Similarly, if the motor fibers are involved, there may be reflex changes, loss of strength, atrophy and even flaccidity.

If the pain is well established, it is usually influenced by one or more motions of the neck. It has been suggested that the cervical foramens narrow in flexion and open in extension. If this were so, one would expect that such pain would be routinely made worse by flexion in all cases. This, however, is not so. In many patients the pain is acutely accentuated by extension; in others, it is made worse by flexion, and in still others it is influenced by rotation.

The pain is increased by anything that tends to elevate the pressure within the spinal meninges, such as coughing, sneezing and defecation. If very severe, it may even be influenced by deep breathing and laughing. If the condition has progressed for some time, the pain may become unbearable. The patient usually carries the head stiffly and resists whichever cervical motion accentuates the pain. The pain is usually worse when the patient is in the recumbent position. It is not uncommonly so severe that ordinary doses of narcotics are of little help.

DIAGNOSIS

If the symptoms that present themselves approximate those described in the foregoing section, it is important to make a thorough differential study, eliminating other disorders that can produce similar symptoms. This can be done by taking the history carefully, making complete orthopedic and neurologic examinations, including roentgen studies with particular attention being paid to special views, and noting the response of the patient to overhead suspension traction (fig. 1).

Roentgen Studies.—The roentgen projections should include: first, an anteroposterior view of the cervical part of the spinal column sufficiently large to include the cervical ribs if they are present; second, a lateral view carefully taken so that it visualizes clearly the lower cervical vertebrae; third, an oblique view of each side of the cervical part of the spinal column. The securing of correct oblique views has been difficult. To secure satisfactory views one must use meticulous roentgen technic. The technic has been carefully outlined by Fuchs.[4] Certain important changes must be noted. Narrowing of the intervertebral disks is significant (fig. 2 *A*). Exostoses must be sought for, particularly at the posterior borders of the vertebral bodies (fig. 2 *B*). Narrowing of the intervertebral foramen must be noted, particularly when associated with narrowing of a disk. It is best seen in the oblique view (fig. 2 *C*). Protrusion of exostoses into the foramen may be visualized both in the lateral and in the oblique views. The absence of any visible changes does not preclude the possibility of impingement on a nerve root. The impingement may be due to capsular and ligamentous thickening, which of course does not reveal itself by roentgenogram. Roentgenograms are usually taken in a single plane, and significant changes which are not seen in that particular plane may be overlooked. It has been demonstrated that hypertrophic changes may be extensive and roentgen evidence of the changes absent.[5]

Suspension Traction as a Diagnostic Aid.—The response of the patient to overhead suspension traction (fig. 1) is a diagnostic aid. The apparatus has a striking

4. Fuchs, A. W.: Cervical Vertebrae, Radiog. & Clin. Photog. **16**:34-41, 1940.

5. Parker, H. L., and Adson, A. W.: Compression of Spinal Cord and Its Roots by Hypertrophic Osteoarthritis, Surg., Gynec. & Obst. **41**:1-14 (Jan. 14) 1925.

psychotherapeutic effect. In using the apparatus an attempt has been made to determine that type of response which may be judged to be psychic and to avoid this side effect if possible.

The patient sits in the apparatus as in figure 1, with the heels resting lightly on the ground. Traction is applied until the buttocks swing clear above the seat. The patient has been previously told that when he is suspended his pain may diminish, disappear, increase or remain unchanged. He is asked to note any change while suspended and any further change on being lowered to the sitting position.

Fig. 1.—Patient seated in the portable apparatus for overhead suspension traction.

If the patient has friction neuritis due to narrowing or crowding of the foramen, as suggested in a foregoing section, the response is typical and constant. The patient will state that when he is lifted off the seat the pain diminishes or disappears. He will state further that it returns to its former intensity the moment he is lowered to the sitting position. Any variation of this response must be viewed with suspicion. If the response is atypical, suspension traction should be repeated a day later. Occasionally the correct response is not present at the original stretching but develops at the next stretching. A proper response to stretching assures an early cure by traction in every instance. A delay in the return of pain after the patient is lowered is a side effect which has been found to be psychic. This delay may vary from a few minutes to several hours or even a day.

DIFFERENTIAL DIAGNOSIS

Impingement on a nerve root of the type under discussion must be differentiated from other conditions which can produce the same symptoms.

Disorders of the Shoulder Joint.—Impingement on a cervical nerve root must first be differentiated from various injuries and diseases of the shoulder joint.

Fig. 2.—*A*, narrowing of the intervertebral disks with compensatory spur formation. *B*, posterior exostosis of the sixth cervical vertebra. *C*, oblique view demonstrating a narrowed intervertebral foramen.

A careful history noting the relation of the pain to motions of the shoulder and leading questions as to whether it is difficult or painful to remove the clothes or comb the hair will usually suffice. Examination of the shoulder in a search

for sensitive points, restriction of motion and accentuation of pain on motion will further establish whether the shoulder joint or any of its allied structures is the source of the pain.

Cervical Rib Syndrome.—The average patient with a cervical rib syndrome is younger than the patient who has impingement on a nerve root. It is rare to see impingement on a nerve root due to foraminal compression much before the age of 35 to 40. The pain of a cervical rib is usually not felt in the neck but is more commonly felt only in the forearm and hand. The paresthesias in the hand are more likely to be confined to an ulnar distribution. They may, however, have a radial distribution. Here too the pain may be influenced by rotation and extension of the neck. It may be made worse by a downward tug of the arm and shoulder. There are frequently vasomotor symptoms, which may vary from dusky discoloration to diminution or obliteration of pulses. Coughing and sneezing may accentuate the pain, probably by jarring the irritated and sensitive structures at the site of the cervical rib. The patient may hold the head stiffly and may dislike moving it. Frequently, holding up the affected arm passively with the other arm will relieve the pain. The response to overhead suspension is exactly what one would expect and is of diagnostic value. Pulling up the head produces the same effect as pulling down the arm and shoulder. Accordingly, the pain is made worse with suspension traction, and the patient states that the pain decreases when he is lowered. The diagnosis is further simplified by roentgen disclosure of cervical ribs. Therefore, although the history and the description of symptoms may not make it possible to differentiate adequately a cervical rib syndrome from the syndrome of impingement on a cervical nerve root, roentgen studies and suspension traction do.

The cervical rib syndrome has been relieved almost consistently by the wearing of an airplane splint. Shrugging exercises designed to develop and shorten the trapezius muscle are instituted as soon as the brace is applied. They do much to decrease the postural descent of the shoulder which precipitates symptoms. Thus the exercise does much to prevent a recurrence. It has not been necessary in my experience to resect a cervical rib or to divide a scalenus anticus muscle for the relief of pain. The following report concerns a case in point.

A 27 year old man, married, first presented himself on Aug. 30, 1940, with a chief complaint of pain in the right arm associated with numbness of the right thumb and forefinger. Twelve days previously he noticed pain in the right scapular region. Four days later the pain traveled to the right side of the neck and radiated into the right arm and forearm. At the same time there developed numbness in the right thumb and forefinger. The pain had been made worse by defecation, coughing and motions of the neck, particularly in extension. He had noticed loss of strength of the right hand.

The patient was well developed and well nourished. He held his neck stiffly, with his head inclined forward and to the right. Rotation of the cervical part of the spinal column to the left or hyperextension of this part of the spinal column accentuated the pain. The right shoulder was normal. The radial pulses were equal. Overhead suspension increased the pain strikingly. The pain returned to its previous state when the patient was lowered.

A roentgen examination made on August 30 was reported as follows: "There is a cervical rib on each side. The supernumerary ribs are unusually long, particularly that on the left side."

The patient was put into an airplane splint, and his condition responded promptly. The acute symptoms subsided in one week, and the residual symptoms disappeared in one month.

Comment: To be noted are the aggravation of the patient's pain by coughing and defecation, motions of the neck and suspension traction.

Scalenus Anticus Syndrome.—This syndrome is not as common as one would expect from the extensive literature on the subject. In my experience the diagnosis has been made rarely, and when it was made there was some doubt as

to the existence of such a clinical entity. When the syndrome is judged to be present, the observer notes that the symptoms are essentially those seen with the cervical rib syndrome. It responds to the use of an airplane splint and to the exercises already described. Overhead traction accentuates the pain.

It has been possible occasionally to cure the condition by intermittent suspension traction in spite of the early accentuation of pain. This may be due to eventual stretching of the scalenus anticus muscle and release from its constricting effect. As for any tenderness over the scalenus muscle, so often described, it has been found to be of no help as it is a fairly constant normal finding. Nachlas [6] in a recent publication disputed the occurrence of a scalenus anticus syndrome and suggested that cutting of the scalenus anticus muscle allows easier extension of the cervical part of the spinal column and that this in turn opens the intervertebral foramen and relieves pressure on the nerve root. I am not prepared to agree completely with him in regard to this conclusion, but the anatomic considerations and reasoning expressed in the publication are interesting and highly suggestive.

Ruptured Intervertebral Disk.—The symptoms of foraminal compression must of course be similar to those produced by herniation of a cervical intervertebral disk. It was possible to stretch a patient with this lesion in the suspension apparatus. There was considerable speculation as to whether marked traction such as this apparatus affords could relieve the symptom momentarily or perhaps allow the disk to shift position so that it might no longer produce symptoms. There was no relief when the patient was suspended, and the response was not typical. Traction of this sort was continued for several days without any particular relief. There was a rather unusual psychic reaction to the traction. The night following the first period of traction the patient slept well for the first time in several weeks. Subsequently the involved region was explored for a ruptured intervertebral disk, and one was removed, with complete cure of the symptoms. Another case may be cited in illustration of this condition.

A 45 year old man was first admitted to the neurosurgical service of Dr. William Jason Mixter, in Boston, because of a pain in the left side of the neck and in the left costocoracoid area, radiating into the left arm, forearm and left second and third fingers, with hyperesthesia and paresthesias of these two fingers. This pain had been present for eight weeks. The patient stated that it was made worse by coughing, sneezing and defecation. There was no injury preceding its onset.

The patient held his head rigidly in the forward and flexed position. All motions of the neck were restricted. Extension of the cervical part of the spinal column increased the pain. The motions of the shoulder joint were normal and did not influence the pain. Neurologic examination revealed nothing but hyperesthesia to pinprick and hypesthesia to brush and vibration in the second and third fingers.

Spinal fluid obtained by lumbar puncture revealed a total protein content of 93 mg. per hundred cubic centimeters. A tentative diagnosis of possible rupture of an intervertebral disk was made, and the patient was discharged to his home on September 21. Directly after this discharge he was seen in my office.

His response to overhead traction was atypical; i. e., the pain was not relieved. Traction was continued for four days and then discontinued. On October 8 the patient was readmitted to the hospital, to the service of Dr. William Jason Mixer. Roentgen studies with iodized poppyseed oil were carried out, and an extramedullary lesion between the sixth and seventh cervical vertebrae was disclosed. On October 13 laminectomy was done and a disk protruding between the sixth and seventh cervical vertebrae, on the left side, was removed, with complete cure of symptoms.

Comment: The physical findings and the history are identical with what one might expect with impingement on a nerve root. The suspension traction response is atypical.

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6. Nachlas, I. W.: Scalenus Anticus Syndrome or Cervical Foraminal Compression, South. M. J. **35**:663-666 (July) 1942.

Neurofibroma of a Cervical Nerve Root.—The symptoms caused by a fibroma of a cervical nerve root may completely simulate those of the condition being discussed, and clinically the two conditions may be indistinguishable, particularly early in their development. As the neurofibroma increases in size, the development of neurologic signs below the level of the lesion is of considerable diagnostic aid. A patient was seen whose symptoms were not unlike those that one expects with impingement on a cervical nerve root. The patient received overhead stretching. The response was atypical. After four days of overhead stretching, lumbar puncture and roentgen studies with iodized oil were carried out and revealed a large filling defect. It is interesting to note that a careful neurologic examination made after the patient was referred for studies by lumbar puncture revealed unmistakable signs below the level of the lesion, suggesting a lesion of the spinal cord. A report of this case follows.

A 47 year old man was seen early in April 1936 because of pain in the right hand and posterior aspect of the right shoulder of two years' duration. The pain was made worse by hyperextension, coughing and defecation.

Examination revealed restriction of extension of the cervical part of the spinal column with accentuation of the pain on forcing extension. The motions of the shoulder joint were normal and did not influence the pain. There was slight atrophy of the muscles of the right arm and shoulder girdle and some weakness of the right hand grip. Response to overhead traction was atypical.

Traction was continued for four days without relief. The patient was then referred to the neurosurgical service of Dr. William Jason Mixter. A careful neurologic examination revealed Hoffmann's sign on the right side and absence of the abdominal and cremasteric reflexes on the right side. Spinal fluid obtained by lumbar puncture revealed a total protein content of 220 mg. per hundred cubic centimeters. Roentgen studies with iodized oil revealed a filling defect on the left side, and on June 25 a large neurofibroma was removed, with cure of the symptoms.

Paralysis of the Serratus Anterior Muscle.—Paralysis of the serratus anterior muscle when due to trauma may produce pain in the neck radiating to the upper scapular region and to the arm. The pain may be referred from there into the hand and may be associated with paresthesias of the fingers. It is not influenced by motion of the shoulder joint. It may be accentuated by hyperextension of the neck. It is not influenced by coughing, sneezing or defecation. The patient's response to stretching of the neck is atypical.

This condition may result from anything which produces a sudden downward thrust of the shoulder. I have observed it following the carrying of heavy logs on the shoulder. In another instance it was observed following the carrying of hods of coal by a patient who was physically unused to such activity. It was seen again following an effort to replace on an overhead shelf a large mixing bowl that threatened to fall, by an upward thrust of the palm and outstretched arm. The condition is easy to diagnose if one remembers to ask the patient to reach forward with the affected arm. If the shoulders are viewed from behind, there is characteristic winging of the scapula (fig. 3). The condition usually responds to the carrying of the arm in the airplane position. Recovery is usually complete. The following report illustrates the differential diagnosis.

A 51 year old man was first seen on Nov. 15, 1941 because of a pain in the left side of the neck radiating into the left arm and forearm and associated with numbness of the finger tips of the left hand. Two weeks previously he had carried some heavy logs on the left shoulder. The pain was not made worse by coughing, sneezing or defecation. The patient was referred for treatment with a diagnosis of cervical radiculitis.

Examination of the patient's left shoulder gave negative results. Hyperextension of the cervical part of the spinal column accentuated the pain. There was no relief of the pain with overhead suspension. The neurologic examination gave negative results. When the patient

reached forward with the left arm held horizontally at the level of the shoulder, there was extraordinary winging of the scapula.

The patient carried his arm in an airplane splint. The pain declined rapidly, and the winging disappeared in two months.

Postural Cervical Strain.—Forward carrying of the head may produce a strain of the cervical spinal muscles with pain in the back of either side of the neck or in both sides of the neck, radiating into one or both arms. There is no accentuation of the pain with coughing or sneezing. The pain is obviously not due to irritation of a nerve root. There may be some discomfiture with certain motions of the neck, due to the tight and shortened structures which are incident to poor

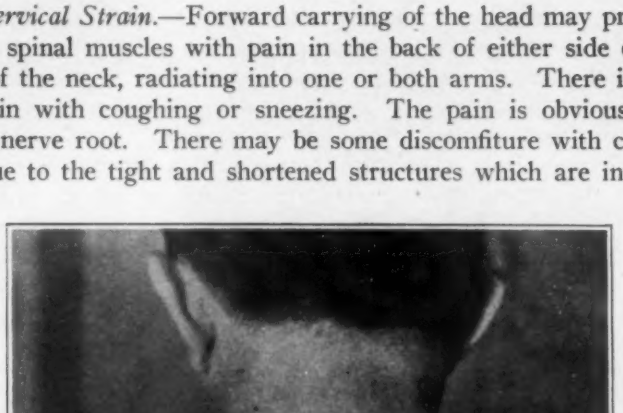

Fig. 3.—Winging of the scapula due to paralysis of the serratus anterior muscle.

posture. It is easy to recognize these cases. Traction has been of some value in stretching shortened structures, particularly if accompanied by postural training.

Angina.—The reference of pain to the precordium with impingement on a cervical nerve root has been responsible for a not uncommon mistaken diagnosis of disease of a coronary artery. The reference of pain to the precordium has been explained by Nachlas,[7] who stated that the medial anterior thoracic nerves originate in the eighth cervical and first thoracic spinal segments while the lateral anterior thoracic nerve originates in the sixth and seventh cervical segments and that these nerves and their branches are motor nerves (i. e., they contain no sensory fibers) but that they "can possess protopathic sensations" so that an

7. Nachlas, I. W.: Pseudo-Angina Pectoris Originating in the Cervical Spine, J. A. M. A. **103**:323-325 (Aug. 4) 1934.

irritation of them may produce a diffuse yet definite pain referred to the terminal portion of the nerve. The absence of a history of pain on exertion and the presence of pain with motions of the neck tend to rule out disease of a coronary artery. Similarly is this true of the continuation of pain for days without constitutional symptoms or other cardiac signs. The relief of pain with suspension traction is a diagnostic aid. The thoracic pain of angina when referred into the arm is more likely to be referred along the inner aspect of the arm, whereas radicular pain is more commonly referred from the cervical part of the spinal column along the outer border of the arm. The differential diagnosis, however, may at times be somewhat difficult. Electrocardiographic studies are of value.

Hypertrophic Arthritis.—Osteoarthritis of the cervical part of the spinal column may in and of itself, without impingement on a nerve root, be responsible for a variety of cervical symptoms. These are usually pain and stiffness of the posterior part of the neck, particularly on arising in the morning. The pain may be referred to the occiput, the back of the shoulders or even into the arms. The reference of pain is not due to irritation of nerve roots but probably occurs in the same manner that osteoarthritis of the hip causes pain to be referred anteriorly along the thigh to the knee. The pain is not made worse by coughing or sneezing. There is no release of symptoms with overhead suspension traction.

Too often the presence of pain and stiffness of the neck associated with roentgen findings of osteoarthritis leads to a diagnosis of compression of nerve roots when none exists.

These patients are helped by overhead traction but fundamentally in the same manner that traction helps any osteoarthritic lesion.

Neurosis.—If one has the opportunity to see large numbers of patients with symptoms referable to the neck, it becomes apparent that the neck is often selected as a site for neurotic symptoms. A tight, drawing sensation in the back of the neck or a conviction that something is out of place is not an uncommon manifestation of emotional exhaustion and maladjustment. The psychic value of overhead traction in this type of patient is marked, if one wishes to use it with positiveness and assurance. It is equally as effective as the supposed manipulative reduction of a supposedly displaced vertebra. The author has experimentally stretched some of these patients with good results.

TREATMENT

Once traction has been decided on as necessary in the light of the history, the results of physical examination and roentgen studies and the response to overhead suspension traction, one has a choice of two types. The suspension type of traction can be continued or it can be replaced by traction in bed. I have preferred to use repeated overhead stretching. The apparatus used for it is a collapsible portable tripod (fig. 1). It can be used in the home, the office or a hospital. A simple but substantial overhead hook or beam to which a set of pulleys and ropes can be secured is equally effective. The traction is usually carried out by the physician. Once intelligent patients have become familiar with the technic, they can carry out the treatment at home. Traction will relieve patients of most of their pain in four to seven days, after which there is gradual disappearance of the residual pain through a period of a week to ten days. The patient is lifted for a moment or two and then lowered. This is repeated for about two to three minutes. This constitutes one treatment period. The suspension treatment is followed by an application of heat and massage to the neck

muscles. The average case calls for three stretching periods on each of the first two days, two on each of the next two days, and then they are spaced out as needed. A Thomas collar has been used occasionally.

This type of traction has three advantages: It permits the patient to be ambulatory; it does not require admission to a hospital. When effective, it is rapid.

For patients who have become difficult to handle because of long-standing pain and for others who prefer bed and hospital care, traction in bed is a good substitute. This type of traction can be carried out effectively in a cardiac bed by using its tilting mechanism as suggested by Dr. Armin Klein (fig. 4). The same effect may be secured by elevating the head of the conventional bed on blocks or on a chair. Traction is maintained by the use of 5 pounds (2.3 Kg.) on each arm of the Sayre sling, or by a 10 pound (4.5 Kg.) total weight if one uses a

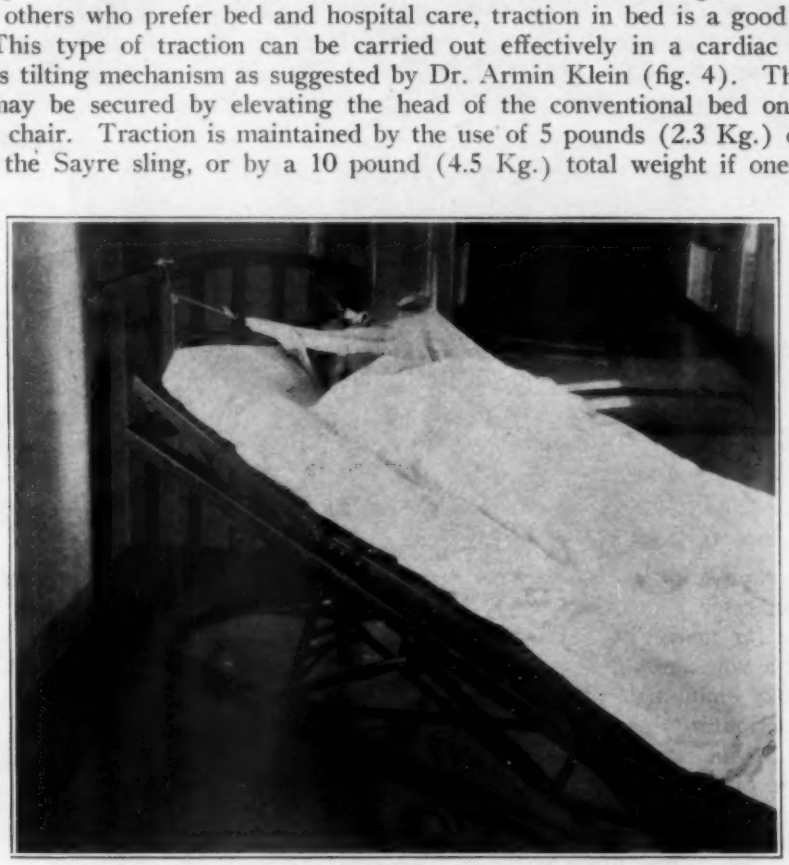

Fig. 4.—Continuous traction applied by the use of the cardiac bed.

crossbar to allow the patient to turn from side to side while maintaining traction. Traction is continued for two hours, after which the patient is allowed a rest of twenty minutes. This procedure is carried out alternatingly throughout the day. If the patient can sleep in the apparatus, he is encouraged to do that.

Recovery with this type of traction is slower than with the overhead type. Many patients find it extremely difficult to stay under continuous traction in bed, because they are uncomfortable.

As to the possibility of danger incident to overhead traction, one can state that it is a technic that can be utilized without fear. It is perfectly safe and may even be carried out by the patient's family after they have been instructed in its proper use. The period of elevation must be short, the ropes used must be of good quality, and if an overhead hook or beam is used as a point from which to hang the apparatus, it must be secure. If the patient has false dental plates, it is wise to have him bite on a flat sterile sponge during elevation.

SUMMARY

Pain in the shoulder girdle, the arm or the precordium may be due to foraminal compression of a cervical nerve root. The diagnosis is suggested by pain uninfluenced by motion of the shoulder and definitely related to motion of the neck. The pain is usually made worse by anything that increases intrameningeal pressure, such as coughing, sneezing and defecation. The condition responds to overhead suspension traction or to traction in bed. The technic of suspension traction is described, and its use as a diagnostic aid is emphasized.

The condition must be differentiated from many other disorders which can produce similar symptoms. The differential diagnosis is not difficult. A careful taking of the history is necessary. The examination must be complete and must include a thorough neurologic study. The response to suspension traction is a distinct diagnostic aid.

371 Commonwealth Avenue.

THE CENTRAL BONE GRAFT IN JOINT ARTHRODESIS

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SPRINGFIELD, MASS.

About two years ago there was presented before the American Academy of Orthopedic Surgeons a brief communication on the technic of using a central bone graft in arthrodesis of the knee or the ankle.[1] The procedure was developed at the Springfield Unit of the Shriners' Hospital for Crippled Children in 1929, and at the time of reporting 10 patients so treated had been followed through their period of growth and the relative leg lengths were compared with those in a like series in which arthrodesis had been achieved by other methods, chiefly the Hibbs method.

Summary of Data on Forty-Four of a Total of Sixty-Seven Patients Treated by Arthrodesis of the Knee or the Ankle

Knee

Patient	Age at Operation, Yr.	Shortening, Inches: Preoperative	Shortening, Inches: Postoperative	Follow-Up, Yr.	Diagnosis
D. B.	5	½	¼	4	Tuberculosis
R. B.	8	½	¼	5	Tuberculosis
J. D.	14	2	2	2	Poliomyelitis
W. B.	10	¾	0	4	Tuberculosis
C. K.	9	¾	0	4	Tuberculosis
A. N.	13	¾	0	3	Sepsis, old
J. A.	10	0	¼	4	Tuberculosis
E. Mac.	6	0	½	5	Tuberculosis
C. St. L.	11	0	0	3	Sepsis, old
R. H.	4	0	0	4	Tuberculosis
R. R.	12	½	¾	2	Tuberculosis
Average		0.5	0.2		

Previously reported cases of arthrodesis of knee, 10; total 21

Grand total..... 67
44

With insufficient data because too recent..... 23

Ankle

Patient	Age at Operation, Yr.	Shortening, Inches: Preoperative	Shortening, Inches: Postoperative	Follow-Up, Yr.	Diagnosis
L. D.	10	¾	2½	4	Poliomyelitis
M. B.	12	1¼	¾	4	Poliomyelitis
J. D.	13	¾	0	2	Tuberculosis
H. B.	13	2	2	2	Poliomyelitis
S. P.	15	1¾	¾	1	Poliomyelitis
P. P.	12	2	2	2	Poliomyelitis
B. M.	13	2	2½	2	Poliomyelitis
P. H.	11	¾	1¼	4	Poliomyelitis
A. F.	14	2½	1¾	2	Poliomyelitis
J. D.	13	1½	¾	3	Spina bifida
B. K.	12	¾	½	2	Poliomyelitis
F. B.	14	1½	1¼	3	Poliomyelitis
J. C.	15	2	2	1	Poliomyelitis
S. B.	14	4	4	3	Poliomyelitis
R. N.	9	0	0	4	Poliomyelitis
N. P.	13	2¼	2	2	Poliomyelitis
R. O.	12	1	1	2	Poliomyelitis
D. M.	16	2	1½	1	Poliomyelitis
R. McD.	12	½	0	2	Poliomyelitis
J. McN.	12	1½	1½	2	Poliomyelitis
J. O.	14	1¾	1½	2	Poliomyelitis
D. B.	12	1¾	2	2	Poliomyelitis
P. B.	12	2	1	2	Poliomyelitis
Average		1.6	1.3		

Total number of cases of arthrodesis of ankle 23

The average age at operation was approximately 9 years, and the resulting inequality of leg length in both groups amounted to about 1 inch (2.5 cm.). Therefore, it appeared evident that a bone graft crossing the central part of the epiphysial disks did not arrest growth.

At the time of reporting these cases I was not able to offer a scientific explanation in support of the indisputable clinical evidence that interference with growth did not result from the procedure. Naturally this led to considerable doubt, and to be doubted by one's friends is distressing, if not entirely damning. It was therefore extremely gratifying when Aries[2] showed experimentally that the longitudinal growth of bone does not take place in the form of lines parallel to the epiphysial

1. Hatt, R. N.: J. Bone & Joint Surg. **22**:393 (April) 1940.
2. Aries, L. J.: Surg., Gynec. & Obst. **72**:679 (April) 1941.

disk but by successive cones from the endosteal surface, each new cone having for its base the peripheral portion of the disk and possessing a wider perimeter than the old.

Sixty-seven operations of the type previously described have been recorded at the Shriners' Hospital, and of these 44 are sufficiently complete as regards preoperative and postoperative measurements and follow-up to permit further evaluation of the method. The accompanying table is more or less self explanatory.

It will be noted that the average age of patients treated by arthrodesis of the ankle is considerably higher than that of patients treated by arthrodesis of the knee. The indication for operation in the former group was talipes calcaneus with an associated quadriceps weakness, the stabilization of the ankle and the foot permitting one to discard supportive apparatus. The number of cases selected for the operation indicates the regard for its usefulness at the Springfield unit of the Shriners' Hospital for Crippled Children.

SUMMARY

Further evidence is offered that a centrally placed graft does not cause arrestment of growth. The usefulness of the procedure justifies the opinions previously stated.

146 Chestnut Street.

HENRY JACOB BIGELOW, ORTHOPEDIC SURGEON

GEORGE H. JACKSON JR., M.D.
EVANSTON, ILL.

Monday, the second day of November 1846, dawned cold and cloudy in Boston and the cheerless sky was leaden throughout the day. Darkness was upon the town before half after five and the cold wind began to blow from the bay, with the evening flow of the tide. Few people walked about the quiet streets, and the clatter of an occasional carriage seemed to intensify the unpleasantness of the weather by raising dismal echoes ordinarily muffled in the bustle of the busy thoroughfares.

In Summer Street, the cheery glow of parlor lights meant that most of the good dwellers in that fine neighborhood were staying indoors for the evening, but at no. 27, Dr. Henry Jacob Bigelow bundled into his great coat and ventured forth to make a call. He walked up to Washington Street, where a north turn and a few more steps brought him to Bromfield Street, turned into Province Court and finally reached Montgomery Place, where he stopped before no. 8 and knocked. While waiting to be admitted, he noted the neat lettering on the doorplate—"Dr. O. W. Holmes"—and felt the pocket of his coat to assure himself that he still had with him the fold of papers he had taken from home.

Dr. Holmes came to the door, greeted the visitor cordially and led him to the library where the Autocrat's comical smile and friendly manner seemed the more pleasant because of the bright glow which came from the fireplace and danced over the red carpet and made grotesque shadows behind the statues of the "Fighting Gladiator" and the "Dying Warrior" on top of the bookcases which lined the room. Titian's portrait of Vesalius looked down from the wall, and Rembrandt's "Three Trees" was obscured in the shadow at a distance from the fireplace. Bigelow laid the fold of papers on the green-covered drum table, and host and guest settled into great armchairs to enjoy the warmth of the fire.

All about the room were books, some of which had belonged to Holmes's father, author of the highly regarded "Annals of America," and there were copies of Holmes's "Poems" and of his "Old Ironsides," once printed as a handbill by a Boston newspaper and so widely circulated that an aroused public sentiment saved the historic ship from proposed abandonment and dismantling. A copy of "The Contagiousness of Puerperal Fever" was there too, still unaccepted and refuted by leading obstetricians three years after its publication. Most of the books in the library dealt with anatomy, and the great folios with their fine plates and stout bindings were the very ones which Harvard medical students may see today if they visit the library in the anatomy building.

Books were familiar friends to Bigelow too, and his father was also a writer, whose essay "On Self-limited Diseases" and handsomely illustrated "American Medical Botany" had been classic contributions to a growing American scientific literature. The younger Bigelow had been awarded the Boylston Prize two years before for his "Manual of Orthopaedic Surgery," and the purpose of the visit to Holmes this evening was to seek the opinion of a valued friend on the merits of another article that had been prepared in the short space of two weeks.

The friendship between Holmes and Bigelow began shortly before 1838, was firmly established during the year Bigelow spent in Hanover, N. H., while attending the course of lectures on anatomy which Holmes gave at Dartmouth Medical School, and endured for well over half a century. There was much in common

between the two men; each was the son of a well known writer and himself an author, both had attended Harvard Medical School and had enjoyed the benefits of postgraduate work on the continent of Europe, at the completion of which they had returned to Boston to assume teaching positions of importance in their alma mater and staff appointments of responsibility at the Massachusetts General Hospital. A further bond was the cordial relationship between Holmes's and Bigelow's father, who had collaborated in 1839 to bring out a revised American edition of Marshall Hall's "Principles of the Theory and Practice of Medicine." It was natural then, when he had prepared the account of a matter he believed of utmost importance, that Bigelow should seek the advice and encouragement of his dear friend the professor.

As the two sat facing each other in the library, Bigelow recounted the story of the great discovery disclosed at the Massachusetts General Hospital on the 16th of October past. He had been present in the surgical amphitheater when Dr. John Collins Warren had allowed Dr. Morton to give the first public demonstration of a new method of producing artificial anesthesia by inhalation, and it had been a complete success. Pain during operations could be abolished and the surgeon would be permitted to operate more deliberately and in regions of the body heretofore inaccessible to the scalpel. Neither the full significance nor the vast potentialities of this new gift to surgery were overlooked by Bigelow, and he had become an enthusiastic devotee of the inhalation of ether and had demonstrated the safety of the procedure by frequently administering the vapor himself. He told Holmes that on the following day he would read the paper he had prepared at the monthly meeting of the American Academy of Arts and Sciences, and apparently received the unreserved endorsement of his friend, for on November 3 was presented to the world the first public announcement of America's greatest contribution to medicine, emancipation from the physical and mental torture which for centuries had been the inevitable concomitant of all but the simplest of surgical procedures.

No printing of Bigelow's paper was ever issued by the American Academy of Arts and Sciences, but in 1852, under the heading "Two Hundred and Seventy Eighth Meeting, November 3, 1846," the following brief note is given: "Dr. Henry J. Bigelow gave some account of a new process of inhalation employed by Dr. Morton, of Boston, to produce insensibility to pain during the performance of operations by the dentist and the surgeon."[1] Had the academy printed the whole address shortly after its delivery by Bigelow, the bibliography of this important writing would have been made a very simple matter. However, the first printing of "Insensibility During Surgical Operations Produced by Inhalation" appeared in the issue of the *Boston Medical and Surgical Journal* for Nov. 18, 1846; so the conscientious bibliophile will want both the academy's notation of the speech and the number of the aforementioned journal for November 18. Probably because of the great demand for copies of this number of the journal, it was reissued later in the year. This item is rarely encountered and is easily mistaken for the original issue. A fourth item plagues the avid collector, the separately issued reprint of Bigelow's paper, an eight page pamphlet without a wrapper, existence of which was unknown until a few years ago, when a number of copies were uncovered in Boston.

Bigelow contributed several important works on anesthetics, among them an analysis of the relative merits and dangers of ether and chloroform, which appeared

1. Proceedings of the American Academy of Arts and Sciences, Boston, Metcalf & Co., 1852, vol. 1, p. 38.

in 1848, and an accurate historical review of the development of inhalation anesthesia in 1876. The first student's textbook to contain a chapter devoted to the use of ether was R. U. Piper's, "Operative Surgery, Illustrated," printed in Boston in 1852.[2] The author dedicated the book to Bigelow, acknowledged his indebtedness to both Holmes and Bigelow for the use of books from their libraries in preparation of the volume and reprinted in its entirety the latter's "Anaesthetic Agents," which had been prepared at the request of the Surgical Committee of the American Medical Association. In this paper Bigelow prophesied that the duty of administering ether "will soon be recognized as involving an entirely distinct responsibility from that of the surgeon who performs the operation." To Bigelow must also be accorded the honor of having transmitted the first communication of the new ether discovery to reach Europe in his letter to Dr. Francis Boott, of London.

Well known as are his writings on anesthesia, Bigelow gave to American medical literature several classic contributions in other fields, particularly on surgical repair of bones and the removal of stones in the bladder. His intense interest in surgical problems dated from his early manhood, and it is related that when Dr. James Jackson tried to persuade the young man to follow his best advantage and choose a medical career in the footsteps of his father, the reply was, "I'll be damned if I won't be a surgeon."

The medical student of a century ago followed the apprentice system then in vogue, whereby he studied under the private supervision of a preceptor for a period of three years, during which he attended two or three courses of lectures at some recognized medical school before taking a final examination for the degree. Pursuant to this custom, Bigelow began his medical education in the office of his father, continued study in Paris, France, for several years and returned to America to take his degree at Harvard University in 1841. Intensive application and close observation had made Bigelow highly competent in the then new arts of auscultation and percussion, and his equal as a microscopist was not to be found in all New England. At the time of his appointment as surgeon at the Massachuetts General Hospital he had become recognized as a most careful, deliberate and competent surgeon, whose ingenuity in devising improved operative technics and in designing or modifying existing surgical instruments and appliances seemed limitless. It is recorded by Dr. H. H. A. Beech that at one time there was hardly an instrument in the cases of the operating room of the Massachusetts General Hospital which had not been designed by the masterful chief of service or which did not show some new advantage from Bigelow's having worked with it. Among such improvement were tourniquets for the arm, wrist and thigh, needle holders, handles for drills, retractors for use in amputation, arterial forceps with a device for disengaging ligatures, an operating chair, an apparatus for angular extension and a most complete autopsy table.

Although the bibliography of Bigelow's papers lists some three score items, they are confined chiefly to the fields of anesthesia, litholapaxy and orthopedic surgery, and it is on the last group that present interest is centered. In 1844 the Boylston Prize was won by Bigelow's "Manual of Orthopaedic Surgery," written in answer to the assigned question, "In what cases, and to what extent, is the division of muscles, tendons, or other parts, proper for the relief of deformity or lameness?" This book was a tall octavo, bound in either red or black cloth, and of about 200 pages. It covered a scope far wider than the prize question designated, and was a most carefully written composition, the first comprehensive

2. Piper, R. U.: Operative Surgery Illustrated, Boston, Ticknor, Reed & Fields, 1852.

presentation of the subject of orthopedics in the United States. Much of the material of the book dealt with subjects not now considered within the province of orthopedic care, such as the chapters on strabismus and stammering, though the former was the most complete discussion that had yet been printed in America, and the latter gave full evidence of the author's thorough understanding of the complicated mechanism involved in the mechanics of speech. Bigelow's discussion of tenotomy, torticollis, clubfoot, spinal curvature, contractions of the hand and fingers, and the appendix, with its instructions on the use of plaster for making casts, is now of only antiquarian interest, since it is no longer the custom to divide the genioglossus muscle to aid an unfortunate stammerer or to cut the lateral ligaments of the knee joints of rachitic children with knock knee. The manual is, however, still a work of historical value for the comprehensiveness of its presentation of the many operations in use at the time of its publication and furnishes a noteworthy picture of the best contemporary French surgery. One statement in regard to the treatment of clubfoot Bigelow caused to be printed in italics: "When in distortion of long standing, with a certain degree of motion still remaining in the joint, a tendon evidently hinders the limb from assuming a normal position, it should be divided."

The first attempt at resection of the head of the femur to be made in this country was reported by Bigelow in 1852. The patient was a young boy with what was apparently tuberculosis of the hip joint complicated by a large abscess and posterior dislocation of the femur. In the belief that removal of the upper end of the dislocated bone would hasten repair of the abscess present, a preoperative decision was made to attempt a hitherto untried method of treatment. Although the patient failed to return to health after operation, great credit must be given the surgeon for his courageous pioneer attempt in a field of surgery previously unexplored.

At the January meeting of the Boston Society for Medical Improvement in 1858, Bigelow exhibited a specimen of stellate crack of the radius removed from a patient who had died as a result of extensive injuries. The correct diagnosis of this type of fracture had been made by comparison with the clinical picture of a similar injury he had observed two years previously. Attention was called to the fact that such an injury of bone involved no displacement of the fragments and that the resultant swelling of the joint and limitation of motion were apt to be mistakenly regarded as the sequels of nothing more serious than a simple sprain of the wrist. Little may be added to Bigelow's explanation of the manner in which such fractures are incurred. He declared that in certain instances of trauma the bones of the wrist acted as a wedge to spread the corresponding hollow of the radial extremity, producing the stellate type of splitting fracture.

As a result of training in the use of the microscope, pathologic processes were interpreted by Bigelow in terms of the cellular pathology of Virchow rather than those of the older gross pathology generally accepted in his day. An instance of his practical application of the newer science is shown in a paper on the periosteal reproduction of the condyles of the humerus, published in 1867, in which is described the excision of the ends of all three bones entering into the formation of the elbow joint in a patient with an infection involving the synovial membrane. The specimen removed after subsequent amputation of the arm showed to Bigelow's satisfaction that the muscle groups at the lower end of the resected humerus were attached to newly formed, curved, cone-shaped condyles resulting from regeneration of periosteal tissue left in position at the time of operation. Further evidence of the application of surgical pathology and the physiology of tissue repair is contained in Bigelow's publication, in 1868, of a report on the handling of

ununited fractures. He described 11 ununited fractures of long bones in all of which he had determined before operation to attempt to obtain solid union by virtue of the osteoblastic properties of the periosteum. How well he performed the technical details involved in the operations is proved by the fact that in 10 of the fractures healing went on to solid union, the single failure being one in which definite infection was present before the surgical intervention. The principles underlying the surgical technic as defined in this report correspond closely with those of the present day, and the warning against unwarranted stripping of the periosteum beyond actual needs is still heeded. Bigelow's particular method of using wires for fixation during the period of bone regeneration, though not now followed, was adequate to provide the immobilization necessary for successful union.

It may still be customary for students reviewing the surgical treatment of fractures to generalize by saying that all injuries to the elbow except fractures of the olecranon are treated by rest in flexion at a right angle. This aphorism harks back to Dr. Bigelow's discussion of methods of treatment of fractures and dislocations of the elbow joint in the *Boston Medical and Surgical Journal* in 1868. The ancestors of the student's general rule is found in the summary of this excellent treatise in the author's words:

> . . . Ascertain if the olecranon is broken, which can be done with comparative ease, as it lies near the surface; this injury requires special treatment. In all other injuries of the elbow joint, whether you are able to make an exact diagnosis or wholly unable to do so on account of the swelling, treat them as though the forearm had been dislocated backwards, and secure the arm at about right angles to an inside angular splint.

A final word of caution is given against overenthusiastic attempts at passive motion in recently injured joints, because of ensuing pain and reaction in muscles if such attempts are carried too far. Bigelow considered a slow restoration of function by gradual use of the injured member on the part of the patient a far better method of therapy.

Best known of Bigelow's orthopedic works is "The Mechanism of Dislocation and Fracture of the Hip," issued in 1869, an epitomization of three papers presented at various times before the Boston Society for Medical Improvement, the Massachusetts Medical Society and the American Medical Association, conveying the results of researches which had extended over a period of eight years. Previous to the appearance of this classic demonstration of a new method of reduction, most hip dislocations had been treated by extremes of traction in the hope that stretching of the muscles would permit the return of the dislodged femoral head, but Bigelow proved by painstaking study of dissections that the anterior portion of the capsule of the hip joint was of very great strength and density and that its two divergent bands, simulating a letter Y, were the chief obstacle to the successful reduction of dislocations. It was shown conclusively in this communication that if the capsular ligaments remained intact in whole or in part after injury they determined the general clinical picture encountered in such cases of trauma and that the muscular resistance to replacement of the femur was of only secondary importance. Reduction by the method devised by Bigelow depended on relaxation of the tensed Y ligament by flexion of the thigh on the pelvis and subsequent traction or rotation of the flexed femur to replace it in the acetabulum, under which conditions of manipulation the strong capsular structures were a help rather than a hindrance to reduction. At the conclusion of the portion discussing dislocations, the book contains a section devoted to the diagnosis and treatment of various types of fracture of the neck of the femur and some notes on pelvic fractures.

In a day when roentgenography was not at hand to render immediate and exact portrayal of the situation and the character of bone injuries, there was much discussion among surgeons of the difficulties of determining whether a fracture of the neck of the femur was of the intracapsular or the extracapsular type. In a communication in 1875, Bigelow felt obliged to go on record with the dictum that such discussions rendered patients no service and that it was far more important in all instances of injury to a hip to decide whether an impaction of the bone was present or not. Studies of numerous sectioned femurs had convinced him that the architecture of the lamellar structure at the junction of the neck and the shaft proved that the former was simply a continuation of the latter, somewhat flattened in order to bear weight more efficiently. He considered that fractures of the neck were of two types, impacted fractures of the base, and unimpacted fractures of the rest of the neck, without regard for the capsule, and that treatment for both types was the same.

In addition to papers already mentioned, Bigelow wrote several short notices on various phases of his work with fractures and in 1878 brought forth the classic exposition of his method of breaking up stone in the bladder and removing the fragments by flushing. Few indeed have won the distinction of contributing accounts of fundamental achievement in as varied fields of medical science as did Bigelow. His works on anesthetics, fractures, and dislocations of the hip and in the province of urology will endure as long as an American medical literature exists.

Paying tribute to his former chief, a Boston physician once wrote that no one who had spent a year at the Massachusetts General Hospital under Dr. Bigelow "could fail to recognize the effect on his own subsequent career of the time thus spent. The subtle influence over his students was felt the more for being insensibly exerted." All who have been privileged to serve under Dr. Osgood know how truly this expression of regard applies to their own former chief, whose kind sympathy and ready understanding will never be forgotten.

> His ready smile a parent's warmth exprest,
> Their welfare pleas'd him, and their cares distrest.

Some of Dr. Osgood's house pupils of a score of years ago recall the thrill of the visit of the honored guests who came in the uniforms of the British Army to pay their respects to Colonel Brackett and Dr. Osgood, who had lately set aside his own uniform. It was a great privilege to see in familiar wards Sir Anthony Bowlby, the renowned British surgeon general, consulting surgeon to the British Expeditionary Forces, tall, erect, taciturn and bronzed with years in the South African service, and to walk far to the left of the genial Welchman, Sir Robert Jones, whose merry smile and ready wit charmed all. They were amazed at the apparently limitless flow of statistics of casualties in the British Army that Sir Anthony quoted from a little black book no larger than a playing card, which he carried in a pocket of his blouse.

A large group made rounds on that well remembered morning. The visitors were met under the rotunda by Drs. Washburn, Brackett and Osgood, together with all members of the orthopedic service, and, with due observance of the proprieties of military rank, proceeded to ward I. An incident of the visit is well recalled by some of the interns present. As the inspection of the ward progressed to the men's side of the ward, there was an obvious stir among the patients as the round came abreast of the bed of a Canadian ex-soldier, bedfast with a badly infected tuberculous knee. The soldier seemed rather frightened at the sight of the British uniforms and in evident confusion raised a trembling, thin, white hand and began

muttering something not heard by any of the group of doctors. With characteristic intuition and keen sympathy for the feelings of others, Dr. Osgood cast a questioning glance in the direction of his senior houseman, and, sensing that the Canadian patient was upset, quietly turned the attention of his followers to the bed beyond, leaving Sir Anthony by the bedside of the soldier to speak a few quiet words. It was not until the next day that the senior intern learned from the soldier the cause of his emotional disturbance. The poor fellow had been helpless to overcome the humiliation of being bedridden and unable to stand at attention properly to deliver the salute due the wearer of the Cross of the Royal Victorian Order; "but the General had shaken his hand, and actually talked with him, and he knew the 'Old Man' under whom he had seen service, and had wished him speedy recovery."

No doubt Henry Jacob Bigelow, the first orthopedic surgeon at the Massachusetts General Hospital, looked down on the gathering of orthopedic surgeons of a later generation and showered his blessing on Sir Anthony Alfred Bowlby, Sir Robert Jones and Robert Bayley Osgood.

840 Forest Avenue.

IMPORTANT WORKS OF HENRY JACOB BIGELOW

Insensibility During Surgical Operations Produced by Inhalation, Boston M. & S. J. **35**: 309, 1846.

Ether and Chloroform: Their History, Surgical Use, Dangers and Discovery, Boston M. & S. J. **38**:229 and 254, 1848.

A History of the Discovery of Modern Anaesthesia, in Clarke, E. H., and others: A Century of American Medicine, 1776-1876, Philadelphia, H. C. Lea, 1876, pp. 73-112.

Manual of Orthopaedic Surgery, Boston, William D. Ticknor & Co., 1845.

Resection of the Head of the Femur, Am. J. M. Sc. **24**:90, 1852.

Stellate Crack of the Radius at the Wrist, Boston M. & S. J. **58**:99, 1858.

Periosteal Reproduction of the Condyles of the Humerus After Excision of the Elbow-Joint, Boston M. & S. J. **76**:345, 1867.

Ununited Fracture Successfully Treated, with Remarks on the Operation, Boston M. & S. J. **76**:297, 1867.

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The Mechanism of Dislocation and Fracture of the Hip, with the Reduction of the Dislocations by the Flexion Method, Philadelphia, H. C. Lea, 1869.

The True Neck of the Femur: Its Structure and Pathology, Boston M. & S. J. **92**:1, 1875.

Litholapaxy or Rapid Lithotrity with Evacuation, New York, William Wood & Company, 1878.

ARTHROGRYPOSIS MULTIPLEX CONGENITA

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"Arthrogryposis (or arthrogryphosis) multiplex congenita" is a term used to designate contractures of the joints. The term "arthrogryposis" is a combination of two Greek words, meaning literally a crooked or bent joint. Various writers have described this condition under different names, such as "multiple congenital contractures of joints," "amyoplasia congenita," "myodystrophia congenita" and "myodystrophia foetalis deformans."

In 1841 A. G. Otto described a case of congenital myodystrophy and in 1905 E. Rosenkranz collected 56 cases which were similar in nature and labeled them arthrogryposis multiplex congenita. Stern [1] in 1923 and Lewin [2] in 1925 used this term in reporting their cases. W. Sheldon [3] in 1932 preferred the name "amyoplasia congenita," believing that the initial lesion is primary aplasia or hypoplasia of certain muscle groups, the defects of the joints being secondary. He confirmed his ideas by investigating the electrical reactions of the affected muscles; these showed no reaction of degeneration but the faradic responses were weak or absent; there were no sensory or trophic changes. D. S. Middleton [4] in 1934 used the term "myodystrophia foetalis deformans," believing that the deformities result from fatty degeneration of muscles occurring during intrauterine life. He expressed the belief that the muscular degeneration is analogous to the muscular dystrophies of later life. The microscopic appearances are very similar. He stated that the muscular degeneration arises fairly late in intrauterine life, after the muscle fibers have been fully differentiated, and that the condition progresses rapdily during late fetal life and ceases at birth.

Arthrogryposis is not mentioned in textbooks of orthopedics except in the recent texts of Campbell [5] and Steindler.[6] These authors have described the congenital contractures of the joints and have recommended early corrective measures.

OBSERVATIONS IN EIGHTEEN CASES

During the years 1925 to 1942, 18 patients (10 males and 8 females) were admitted to the Children's Hospital in Boston with the diagnosis of arthrogryposis. The ages ranged from 5 days to 10 years and 7 months. There is no history of deformity in relatives or parents in 17 of the cases. In 1 case the maternal uncle, aged 20 years, has never walked.

The following tabulation summarizes the combinations of abnormalities of the joints in these patients.

Patients	Areas Involved
2	Hands and feet
1	Hands, feet and hips
2	Hands, feet, knees and hips

1. Stern, W. G.: Arthrogryposis Multiplex Congenita, J. A. M. A. **81**:1507 (Nov. 3) 1923.
2. Lewin, P.: J. Bone & Joint Surg. **7**:630, 1925.
3. Sheldon, W.: Arch. Dis. Childhood **7**:117, 1932.
4. Middleton, D. S.: Edinburgh M. J. **41**:423, 1934.
5. Campbell, W. C.: Operative Orthopedics, St. Louis, C. V. Mosby Company, 1939.
6. Steindler, A.: Orthopedic Operations, Springfield, Ill., Charles C Thomas, Publisher, 1940.

Patients	Areas Involved
1	Hands, elbows, feet and knees
1	Feet, knees and right hip, which is dislocated
1	Hands, feet, elbows, knees, hips
1	Hands, feet and hips, which are both dislocated
1	Feet and right hip, which is dislocated
2	Feet, knees, hips and spine
1	Feet, knees, hands and hips, both of which are dislocated
2	Feet, hands, elbows and hips, which are both dislocated
1	Feet, hands, knees, hips and spine
1	Feet, hands, knees, shoulders
1	Feet, hips and spine

In addition to contracture of the hip, 5 patients had frank dislocation of the hip, bilateral in 3, unilateral in 2. Several of the children presented additional anomalies. There were 2 with undescended testicles, 3 with inguinal hernia and 1 with a cleft palate.

On examination in cases of arthrogryposis the extremities present a unique appearance. They lack the usual anatomic contours, having instead a stuffed sausage–like appearance. Very little muscle is palpable. The structures overlying the joints feel thickened and contracted. Dimples are frequently seen over the patellas and the elbows. In most of the involved muscles passive correction of the contractures is possible to a few degrees, although some are rigid, allowing no correction. These gross abnormalities are symmetric, distinctive and readily recognizable.

Histologically there is atrophy and fat replacement of the involved muscles.

Roentgen films taken in the first few months of life show deficient muscle shadows, with increased density in the capsular areas, without changes in the bone. Older infants and children show secondary deformities of bones associated with long-standing contractures of the soft tissues.

In general, the younger patients in this series were treated in this order: (1) manipulations without anesthesia, (2) supports, (3) anesthesia, manipulations and supports and (4) surgical corrections.

The older patients were treated by operative procedures selected as most suitable for the correction of the individual deformity. These procedures were fasciotomy, capsulotomy, lengthening of tendons, open reduction of hips and arthrodesis for the correction of club feet.

The end results varied in relation to the number of deformities present and the time of treatment. As is true of all congenital deformities, the best results were obtained with the early institution of corrective measures. These badly disabled children, presenting at birth a discouraging picture, were definitely improved by treatment.

REPORT OF AN ILLUSTRATIVE CASE

The case record of a patient illustrating the progress made from the age of 3 weeks to that of 26 months follows:

R. S., a boy aged 3 weeks, was admitted to the outpatient department of the Children's Hospital in Boston, Aug. 29, 1940, for the treatment of deformed upper and lower extremities, noted at birth. The father, aged 32 years, had diabetes. The mother, aged 22 years, was well except for occasional attacks of dermographia. The patient was the only child; there had been no other pregnancies. The parents reported no deformities in their families.

At the birth of the child the mother had twilight sleep and was "on the delivery table for twenty-four hours." No instruments were used at delivery, although there was some type of

manual manipulation to improve the position. Episiotomy was done. No cyanosis or convulsions followed birth.

The infant since birth had been fed by formula. There was considerable difficulty in feeding him, due to vomiting. Vitamins C and D were given at 3 weeks of age.

Immediately after birth it was noted that the baby had deformities of the shoulders, elbows and hands, contracted knees and clubfeet.

On examination, both shoulders were adducted with passive abduction to 90 degrees. The deltoid muscles were small, with very little muscle that was palpable. The elbows were extended to the extreme degree and permitted passive flexion of 45 degrees on the right and

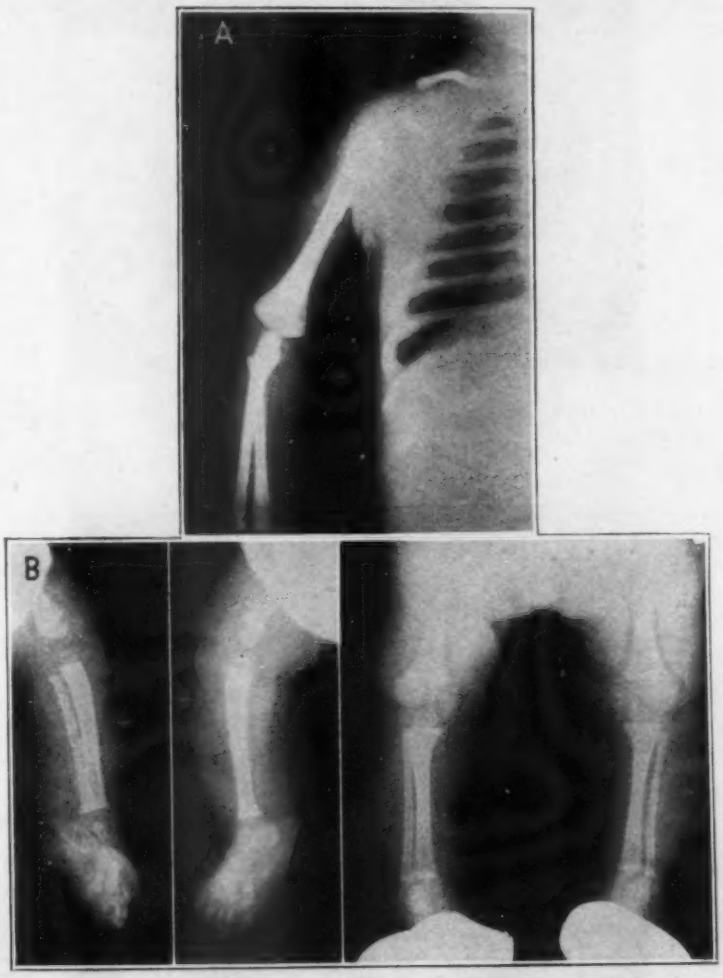

Fig. 1.—*A*, roentgenogram showing poorly developed muscles of the upper arm. *B*, roentgenograms showing diminished muscle shadows and thickened periarticular structures.

80 degrees on the left. Supination of the forearm was not possible on the left; 15 degrees was obtainable on the right. Pronation of the forearm on the left was 20 degrees, that on the right was 15 degrees. Extension of the wrist on the left was 20 degrees; that on the right, 20 degrees. Flexion of both wrists was possible to 50 degrees. Knees were permanently flexed to 25 degrees, with further flexion to 120 degrees. Both feet were in rigid equinovarus position.

Roentgenograms of the upper and lower extremities showed deficiency of the muscle tissue shadows. The capsules and the ligaments appeared thickened. The bones were normal except for the deformities in the clubfeet.

Fig. 2.—*A*, patient at 3 weeks. Note contractures of the feet, knees, fingers and elbows. *B*, rigid talipes equinovarus.

Fig. 3.—*A*, patient at the age of 10 months, prior to surgical correction of the feet, *B*, lower legs of the patient twelve weeks after operation—aged 12 months and 2 weeks.

The child was given outpatient care, consisting of manipulations of the upper and lower extremities with weekly changes of casts to the feet, for a period of ten months. During this time he had recurrent infections of the upper respiratory tract with otitis media.

The infant at 10 months of age was admitted to the hospital for surgical correction of his feet and further manipulation of his upper extremities. Lengthening of both heel cords and posterior capsulotomy were done, and casts were applied with the feet in marked dorsiflexion, abduction and eversion. Following an uneventful convalescence of three weeks, the boy was again followed in the outpatient department. There physical therapy was given to the upper extremities three times weekly. His feet were protected in casts for eight weeks, followed by manipulations three times weekly. Bivalved casts were used between treatments. At 16 months of age he began to walk in corrective shoes. His feet were manipulated daily at home, and Dennis-Brown shoe splints were used during his day and night sleeping periods.

At the time of writing the patient is 2 years and 3 months of age and is attending a nursery school. Although he has not a complete range of motion of his elbows and shoulders,

Fig. 4.—*A*, patient at the age of 26 months, showing corrected elbows. *B*, corrected feet and knees.

he uses his hands and arms freely in performing the various nursery activities. He is talking well for a child of his age.

His last examination, in November 1942, showed a good hand grasp, with some weakness; there were no contractures of fingers or wrists; the elbows had active flexion of 90 degrees and extension of 160 degrees; shoulder abduction was, active, 60 degrees; passive, 90 degrees. Both feet were flexible and corrected 10 degrees beyond neutral in dorsiflexion, abduction and eversion. He walked and ran well and easily. His arms swung freely but not completely.

Besides the orthopedic treatment, this patient has been given an abundance of vitamins, including vitamin E. He has been receiving vitamin E since June 1941, when he was 10 months of age, and is now having 15 drops daily of a preparation of this vitamin.[7]

270 Commonwealth Avenue.

7. The preparation used is tocopherex (Squibb), a concentrated distillate of vegetable oils each cubic centimeter of which represents 400 mg. of mixed alpha, beta and gamma tocopherols, equivalent in vitamin E activity to 250 mg. of alpha tocopherol.

WIRE FIXATION OF FRACTURES OF THE PROXIMAL THIRD OF THE HUMERUS

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ST. LOUIS

A relatively high percentage of fractures of the proximal third of the humerus in which the fragments are completely displaced are difficult or impossible to reduce satisfactorily by manipulation. This is especially true of the fracture-dislocations and of those fractures in which the head of the humerus is also broken into two or more pieces. These fractures are likewise difficult to treat by traction, because the short proximal fragment tends to be abducted and rotated outward while the pectoralis major and subscapularis muscles tend to draw the proximal end of the distal fragment inward and forward. When traction is applied in abduction, the proximal end of the distal fragment is drawn forward and downward by the pectoralis major and latissimus dorsi muscles (fig. 1 *A*).

On account of the difficulties mentioned, it is my custom to treat these fractures by open reduction, frequently without even attempting treatment by closed manipulation or traction. This is particularly true since I have learned to place a powdered sulfonamide compound in the wound and thus lower the chance of infection almost to the vanishing point.

The operative reduction is relatively simple and may be done with the patient under general or local anesthesia. The technic is as follows:

The patient is placed on his back on an ordinary operating table and is so draped that the fractured extremity can be manipulated without the operative field becoming contaminated. The fractured arm lies at the side with the elbow resting on a sand bag and the forearm resting on the chest.

A vertical incision about 3 inches (7.5 cm.) long is made on the anterolateral aspect of the shoulder. The incision begins just below the margin of the acromion and is parallel with the fibers of the deltoid muscle. The fibers of this muscle are separated by blunt or sharp dissection, care being taken not to injure the circumflex nerve, which lies on the deep surface of the muscle near the middle of the incision and frequently at the level of the fracture.

The muscle is retracted gently, leaving the nerve stretched across the wound. The distal end of the proximal fragment lies just beneath the deltoid muscle and is easily identified. The proximal end of the distal fragment lies some distance inward and forward and can be felt with the finger. The clot is removed, an assistant makes moderate traction on the arm with the elbow flexed, and the surgeon reaches in with a large Kocher forceps or a small bone-holding forceps, grasps the shaft of the humerus near the fracture line, pulls it directly outward and opposes its end to that of the proximal fragment.

If the fragments are quite stable when reduced (fig. 2 *A*), no internal fixation is necessary. The powdered sulfonamide compound is implanted in the wound, the wound is closed in layers and the arm is immobilized across the chest with a Velpeau bandage. As a rule, only one small blood vessel is tied. This is the vein lying alongside the circumflex nerve. If it is torn, care must be taken not to damage the nerve in clamping and tying the vein.

From the Department of Surgery of the Washington University School of Medicine.

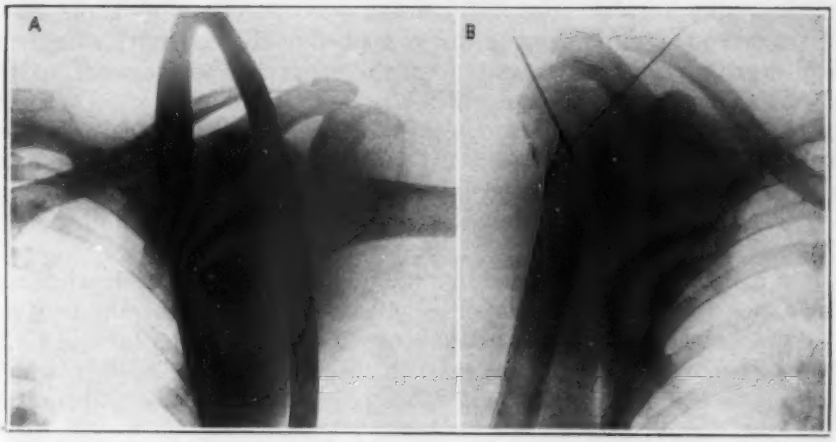

Fig. 1.—*A*, fracture of the proximal third of the humerus. The roentgenogram shows the position obtained by traction in a Thomas arm splint. *B*, the same fracture as in *A* after open reduction and immobilization by two Kirschner wires, which were removed later. The fracture of the head of the bone is not visible in the roentgenogram.

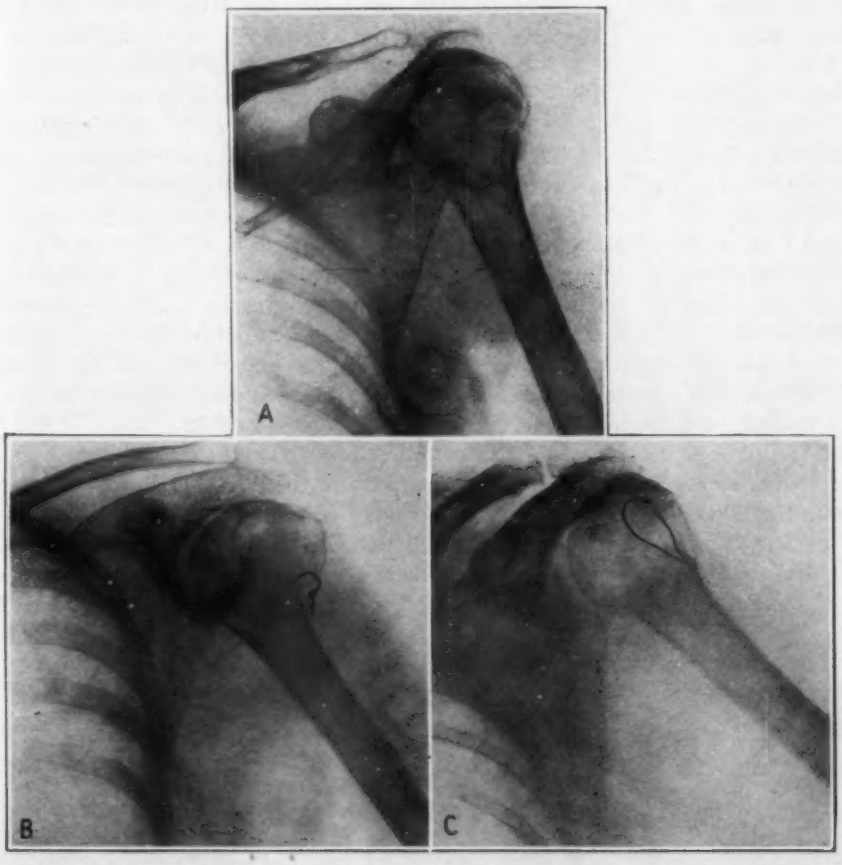

Fig. 2.—*A*, fracture similar to that in figure 1 after open reduction. The fragments were stable when reduced, and no internal fixation was necessary. *B*, a similar fracture fixed by a single wire loop. *C*, a similar fracture fixed by a wire mattress suture.

Ten days after the operation the Velpeau bandage is removed, the cutaneous sutures are taken out and a hanging cast is applied to the extremity with the elbow flexed 90 degrees. The cast extends from the upper arm to the wrist and is suspended at the wrist by a bandage which passes around the neck. The patient is then instructed to exercise the shoulder muscles several times daily by bending forward and swinging the arm backward and forward and across the body and in circles while the wrist is supported by the sling from the neck. About three or four weeks later, the cast is removed, and the exercises are continued until the shoulder is normal.

In most instances it will be found that the fragments are not stable when reduced and that some form of internal fixation is advisable. I have generally used a small loop of stainless steel wire, either a double or a single loop (fig. 2 *B* and *C*). The double loop is more secure, and the twist in the wire is placed farther away from the floor of the subdeltoid bursa and thus is less apt to cause pain afterward. However, the double loop is more difficult to apply, and its use prolongs the operation. As most of the fractures of the proximal third of the humerus occur in older persons, this is not desirable. Moreover, if the ends of the fragments are comminuted (and they often are), one may not find suitable spots for the four drill holes necessary for the double loop or mattress wire suture.

In a recent case in which the head of the humerus was split and the greater tuberosity comminuted, it was found that two Kirschner wires drilled through the proximal fragment and obliquely through the cortex of the distal fragment not only fixed the fragments of the head but also afforded adequate fixation of the two major fragments (fig. 1 *B*). With the fracture reduced, suitable points on the lateral and superior aspects of the shoulder are selected and the Kirschner wires are pushed through the skin down to the bone and then drilled through the two fragments. They are then cut off, leaving about an inch (2.5 cm.) of each wire protruding from the skin, and the wound is closed and the arm is immobilized in a Velpeau bandage. The protruding ends of the wires are covered with a gauze pad, and ten days after the operation the cutaneous sutures are removed, the hanging cast is applied and the swinging exercises are started. If the wires are so placed that the exercises are painful, the latter are postponed until the wires have been removed. At the end of two or three weeks, depending on the stability of the fragments, the wires are pulled out and the exercises are continued as described in a foregoing paragraph.

The use of Kirschner wires is the simplest and most satisfactory method which I have found for fixing fractures of the proximal third of the humerus, and they eliminate the necessity of leaving a foreign body in an area where pain is especially prone to occur. As the wires are directed backward and downward there is little danger that their protruding ends will damage an important blood vessel or a nerve.

TREATMENT IN CASES OF SLIPPED CAPITAL FEMORAL EPIPHYSIS AT THE MASSACHUSETTS GENERAL HOSPITAL

ARMIN KLEIN, M.D.

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AND

JOHN A. REIDY, M.D.

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A study of the records of patients treated at the Massachusetts General Hospital for epiphysiolysis or for slipped upper capital femoral epiphysis was made in an attempt to determine what has been accomplished in treating these patients, what progress has been made in methods of treatment and what procedures should continue to be used and what procedures should be discarded. We surveyed all records filed at this hospital in cases of slipped femoral epiphysis, since the condition was recognized here. We found that various forms of treatment had been used, and we expect that analyses of the results will afford indexes to the proper treatment in such cases.

L. Albert Key [1] and Philip D. Wilson,[2] in previously published monographs, reviewed the cases of slipped upper femoral epiphysis as recorded in this hospital from 1904 to 1923. They reported that in 30 cases treatment was by manipulation and plaster fixation or by open reduction and plaster fixation. Key concluded that "forcible manipulation of an old case tends to result in increased stiffening of the hip and is not justified by the results obtained." Wilson disclosed that in the majority of cases the findings at the time of open operation indicated that manipulation could not have succeeded if it had been tried. He therefore advocated open reduction at the seat of the deformity and postoperative fixation with plaster.

The end results obtained during this period apparently were not satisfactory enough to warrant continued reliance on these methods of treatment. A survey of the records of 39 patients treated during the years from 1924 to 1932 still revealed some poor results from the old methods of manipulation and plaster fixation or from open reduction and plaster fixation but revealed better results from open reduction, nailing with a three-flanged nail and early mobilization.

In the past decade the treatment for slipped epiphysis has been rather variable but lately has shown some signs of consistency. Thirty-two patients were treated during this period. Seven patients had bilateral slipped epiphysis; therefore, 39 hips were examined and 36 of these were treated in this clinic.[3]

1. Key, J. A.: Epiphyseal Coxa Vara or Displacement of the Capital Epiphysis of the Femur in Adolescence, J. Bone & Joint Surg. **8**:53-117, 1926.

2. Wilson, P. D.: Displacement of Upper Epiphysis of Femur Treated by Open Reduction, J. A. M. A. **83**:1749-1756 (Nov. 29) 1924.

3. The statistics on patients with epiphysiolysis treated at the Massachusetts General Hospital in the period from 1933 to 1942 follow.

Number of patients with epiphysiolysis:

32 (In 7 [21%] condition was bilateral; second hip slipped 7 months to 2 years after slipping of first hip)

Sex and ages of patients:

10 (31.2%) females—ages 8 to 14—average age 12 ±

22 (68.8%) males—ages 9 to 16—average age 13 ±

(Footnote continued on next page)

The patients fall into three classifications according to the methods of treatment used: a miscellaneous group, with multiple forms of treatment; a group treated by arthrotomy, reduction and lateral nailing, and a group treated by lateral nailing in situ.

A method of appraising hip function was suggested by the "index of motion" table of Ferguson and Howorth.[4] Briefly, it consists of designating a factor for each motion according to its importance. The amount of demonstrable motion is multiplied by this factor to give a product for that particular motion. The sum of these products represents "the index of hip motion." An example of the use of the index of motion in a specific case follows:

	Motion	Factor	Product
Flexion	145°	0.4	58
Abduction	45°	0.4	18
Adduction	30°	0.2	6
Rotation			
Internal	30°	0.2	6
External	60°	0.1	6
Extension	10°	0.1	1
			95

On this basis the index of hip motion was then computed for the affected hip as compared with the sound hip. Since such an index of motion does not include pain or limp, it is felt that it lacks certain elements which determine true function of a hip. For this reason, we have assigned only one third value to the index of

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Physical types:
Females—6 obese; 1 tall and thin (types of 3 unknown)
Males—16 obese; 2 tall and thin (types of 4 unknown)

Side involved:
Females—5 right; 3 left; 2 bilateral (left hip first in one case; right hip first in other case)
Males—6 right; 12 left; 4 bilateral (2 right hip first; 2 left hip first)

Trauma as an etiologic factor in 37 + %:
4 of 10 girls — 40%
8 of 22 boys — 36 %

Duration of Symptoms:
Females—2 weeks to 1 year—average 3.4 months
Males—1½ weeks to 2 years—average 7 ± months

Treatment before entering hospital:
No treatment 21
Rest in bed 5
Treatment of feet 3
Manipulation and cast 2
Traction 1

Diagnosis (at this hospital) before roentgen examination:
Correct in 81%
Incorrect—viz., tuberculosis, sepsis and strain—in 19%

Degree of slipping:
Minimal (i. e., 1 cm. or less) in 50%; of these 83% were boys and 17% were girls
Marked (i. e., over 1 cm.) in 50%; of these 61% were boys and 39% were girls

4. Ferguson, A. B., and Howorth, M. B.: Slipping of the Upper Femoral Epiphysis: A Study of Seventy Cases, J. A. M. A. **97**:1867-1872 (Dec. 19) 1931.

motion and an equal value to the element of painlessness and to that of absence of limp, calling the total of these three elements the percentage of true normal function of the hip.

Index of Motion	Painlessness	Absence of Limp	Total Percentage of True Function of Hip
33.3	33.3	33.3	100

The results of the miscellaneous types of treatment are analyzed in table 1. Ten patients were observed for fourteen to one hundred and four months. The first 6 whose cases are charted showed marked slipping; the last 4, minimal slipping.[5]

In the first 3 patients, with osteotomy at a distance from the seat of the deformity, i. e., at the distal portion of the neck or at the subtrochanteric region,

TABLE 1.—*Miscellaneous Types of Treatment*

Name	Age	Months After Operation	Postoperative Shortening, Inches	Treatment	Percentage			Total Percentage of Function
					33.3 Index of Motion	33.3 Pain	33.3 Limp	
C. de J.	14	39	1½	Osteotomy at distal neck with nailing; sepsis; cup arthroplasty	2.0	33.3	33.3	35.3
W. M.	14	14	½	Subtrochanteric osteotomy and Thornton plate	0.0	0.0	0.0	0.0
W. B.	15	25	2½	Osteotomy at distal part of neck; sepsis; cast	0.0	33.3	0.0	33.3
C. C.	13	104	½	Manipulation and spica	15.0	33.3	33.3	81.6
C. C.	14	26	¼	Open reduction and nailing; acetabuloplasty	12.1	33.3	0.0	45.4
N. B.	14	31	1½	Manipulation, lateral nailing; open reduction and nailing; cup arthroplasty	7.0	22.2	0.0	29.2
Average								37.4%
C. McK.	13	38	0	Drilling	28.9	33.3	33.3	95.5
A. P.	12	87	½	Open operation and drilling	29.8	25.0	33.3	88.1
A. C.	13	63	0	Traction	17.4	33.3	33.3	84.0
C. S.	14	81	⅝	Biopsy	16.3	33.3	33.3	82.9
Average								87.6%

were the three poorest results seen in the entire series. All 3 patients had a marked limp. One of the 3 had marked pain. Two had no motion in the involved hip, and the third had practically no motion. The total percentage of function for the involved hip ranged from 0 to 35.3 per cent, averaging only 22.8 per cent of normal. To be sure, a group of 3 is a small sample on which to base conclusions, but when the results observed in them are uniformly so poor, it seems as if this type of procedure might be reserved for older neglected deformities. It seems obvious that to restore normal anatomic relationships the attack should be made on the deformity at its site rather than at a more remote point.

The last 4 patients, with minimal slipping, showed good results with drilling or no treatment. The average total percentage of function was 87.6 per cent.

5. A slip of the epiphysis backward and downward from the femoral neck amounting to no more than 1 cm. was considered to be minimal. Any slip greater than 1 cm. was considered marked.

Table 2 presents the data on 11 patients with marked slipping who were treated by arthrotomy and osteotomy through the epiphysial plate and nailing. In each case an attempt was made to replace the head in its anatomic position and to fix it there by inserting a three-flanged nail from the lateral aspect of the femur through the neck and across the epiphysial plate into the head.

Postoperative treatment in most instances consisted of suspension in traction for two to three weeks. The patient was then allowed to be up and about with

TABLE 2.—*Arthrotomy, Reduction and Lateral Nailing*

Patient	Age	Months After Operation	Postoperative Shortening, Inches	Percentage: 33.3 Index of Motion	Percentage: 33.3 Pain	Percentage: 33.3 Limp	Total Percentage of Function
S. P.	14	11	0	22.7	30.0	30.0	82.7
L. St. G.	11	26	½ (1 cm.)	29.6	30.0	30.0	89.6
A. S.	12	59	1⅜ (3.5 cm.)	15.8	33.3	0.0	49.1
S. B.	8	63	2¼ (5.5 cm.)	7.0	33.3	0.0	40.3
J. D.	15	94	⅜ (0.95 cm.)	21.1	33.3	33.3	87.7
F. J.	16	96	½ (1 cm.)	24.9	33.3	33.3	91.5
C. J.	12	87	⅜ (0.95 cm.)	23.5	33.3	33.3	90.1
J. J.	16	54	0	15.2	33.3	25.0	73.5
R. L.	14	80	½ (1 cm.)	30.5	33.3	33.3	97.1
C. M.	11	61	½ (1 cm.)	33.3	33.3	33.3	100
G. O.	13	77	0	18.5	25.0	0.0	43.5
Average		64.3	Under ⅜ (1.5 cm.)	....	....	....	76.8

TABLE 3.—*Lateral Nailing in Situ*

Patient	Age	Months After Operation	Postoperative Shortening, Inches	Percentage: 33.3 Index of Motion	Percentage: 33.3 Pain	Percentage: 33.3 Limp	Total Percentage of Function
J. M.	9	26	0	33.3	33.3	33.3	100
D. McM.	16	15	⅝ (1.5 cm.)	23.7	33.3	33.3	90.3
M. H.	15	20	0	32.5	33.3	33.3	99.1
R. G.	13	12	0	33.3	33.3	33.3	100
R. F.	13 (L)	12	0	31.4	33.3	33.3	97.0
	14 (R)	5	0	24.1	33.3	33.3	90.7
A. W. Jr.	13	29	0	21.5	33.3	33.3	88.1
C. B.	10	39	⅜ (0.95 cm.)	31.0	33.3	33.3	97.6
M. G.	12	39	¾ (2 cm.)	32.3	33.3	33.3	98.9
D. R.	13 (L)	48	⅜ (0.95 cm.)	25.3	33.3	33.3	91.9
	15 (R)	30	...	24.0	33.3	33.3	90.6
M. S.	12	48	⅝ (1.5 cm.)	30.5	33.3	33.3	97.1
E. T.	13 (L)	13	...	26.9	33.3	33.3	93.5
	12 (R)	25	¾ (2 cm.)	26.9	33.3	33.3	93.5
Average		25	Less than ¼ (0.64 cm.)	....	....	....	94.8

a non-weight-bearing splint and a high sole on the unaffected side. The brace was worn until roentgen examination disclosed obliteration of the epiphysial line and restoration of the epiphysis with bone comparable in vitality to the adjacent bone of the pelvis and the femur. This whole group was followed for an average period of sixty-four and three-tenths months. Their average index of motion was about two thirds of normal. Only 3 of the 11 patients had pain, and this was of minor degree; 5 had no limp, 3 had a bad limp and 3 had only a slight limp. Their average percentage of normal hip function was 76.8 per cent.

The next and final group (table 3) consists of 11 patients, 3 with bilateral involvement. These patients had only minimal slipping of the epiphysis, less than

1 cm. in extent. They were all treated by lateral nailing in situ without arthrotomy. The nail was introduced into the lateral cortex of the subtrochanteric region of the femur and was driven through the neck, across the epiphysial plate and into the head without any attempt at altering the existing relationship of the femoral head and neck. The hip was immobilized postoperatively by Buck's extension apparatus until the sutures were removed. The patient was then allowed to be up and about on crutches or with a brace until motion in the involved hip joint was free and painless. The average period of observation was twenty-five months. The average index of motion was about 84 per cent of normal. Pain and limp were absent in all cases. The average percentage of normal hip function for the entire group was 94.8 per cent.

COMMENT

Analysis of the results of treatment in cases of slipped capital femoral epiphysis revealed the ultimate aim to be a fusion of the epiphysis to the neck of the femur in the position in which it was first discovered or in a corrected, anatomic position. To be sure, the accomplishment of this purpose meant cessation of growth in the involved epiphysial region, but it also meant the termination of farther slipping of the epiphysis, and the last consideration is paramount.

Earlier attempts at correction of the deformity by forcible "closed" manipulation and fixation in plaster led to stiffening of the hip. Later attempts at open reposition of the slipped epiphysis and fixation in plaster gave unsatisfactory results, chiefly because of the resulting traumatic arthritis. But the surgeons learned from these later attempts that though roentgenograms may show a marked widening at the epiphysial plate, the epiphysis is quite firmly attached to the neck, and rarely can this relationship be changed by manipulation without osteotomy. Then the addition of the three-flanged nail to the armamentarium of the orthopedic surgeon made it possible for him to replace the epiphysis in its anatomic position, to fix it there with the nail and then to start early mobilization of the hip joint. Plaster casts became unnecessary. Traumatic arthritis became more infrequent and less severe.

Greater experience with such patients sharpened knowledge of the symptoms. This resulted in the early diagnosis, made when the slip was still minimal. In addition, further experience in the follow-up clinic prompted mindfulness of the early signs and symptoms of involvement of the opposite hip, because statistically about 20 per cent of those affected with a slipped upper femoral epiphysis in one hip will, within two years, have bilateral involvement.

We have surveyed the records of 32 patients with slipping of the upper femoral epiphysis in 39 hips who were treated at the Massachusetts General Hospital during the last decade. As a simple method of evaluating the function of the treated hip so that it might be compared with that of the patient's normal hip, we used a modified Ferguson-Howorth "index of motion" table.

Thus we appraised function in 3 cases of marked slipping in which osteotomy was done at a point distal to the site of the deformity, i. e., distal to the epiphysial plate. The results were uniformly poor (table 1)—in fact, the poorest results of the entire series. We feel this method for the treatment of a patient with a slipped epiphysis should be discarded. It might be reserved for those with old traumatic arthritis and deformity, who could be helped by alteration of the mechanics of the hip joint.

The present treatment, arthrotomy of the hip joint, reposition of the displaced epiphysis on the neck and fixation by means of a three-flanged nail, followed postoperatively by traction and the wearing of non-weight-bearing splints, should be

continued for patients with marked slipping of the epiphysis. The group treated thus showed hip function 76.8 per cent of normal (table 2). This contrasts favorably with a comparable group treated by miscellaneous methods, such as osteotomy distal to the epiphysial plate, whose hip function was only 37.4 per cent of normal.

Lateral nailing in situ, without arthrotomy and without correction of the early deformity, is the best method of treatment for patients with only minimal slipping of the epiphysis, and this in spite of the good results obtained from drilling and traction. We have seen 2 hips with minimal slips left untreated except for the use of non-weight-bearing splints continue to slip to a marked degree. Since drilling and traction do not immobilize the epiphysis any more than a non-weight-bearing splint, we advocate lateral nailing in situ. Such a procedure demands no more skill of the surgeon and entails no more risk on the part of the patient than does the drilling operation. Lateral nailing is a relatively simple procedure for the surgeon who has been adequately trained. But if minimal slipping is allowed to progress, open reduction and nailing become necessary. This is a relatively difficult procedure even in the hands of the orthopedic surgeon. The results from arthrotomy, reduction and nailing, averaging 76.8 per cent of normal hip function, are not as good as the results from lateral nailing in situ. The latter method of treatment afforded by far the most gratifying results, averaging 94.8 per cent of normal hip function. This is also better than the 87.6 per cent for drilling and traction.

We therefore wish to stress the importance of diagnosing the condition early, while the slip is still minimal, of obtaining early fixation by lateral nailing in situ, of mobilizing the hip early after operation, and of recognizing early a possible slip in the contralateral hip.

ADVENTITIOUS BURSAS

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Bursas have been defined as the synovial strata which are found outside of joints to reduce friction.[1] Normally they are located between the skin and bony projections and between tendons and prominences over which the tendons move.[2] Albinus,[3] while he was not the first to discover these synovial sacs, described their occurrence between muscles and gave them the name bursae mucosae. The normal bursas about the joints develop as a rule during the latter half of intrauterine life. Complete maturation of the bursal cavity and definition of its outline are believed to come only with fetal movement. Occasionally, normal bursas develop first in early childhood, and instances have been reported in which even the larger bursas were not present in adult life.[4]

In addition to the usual bursas about the joints present at birth, other bursas develop not infrequently beneath the skin or about the tendons to prevent excessive friction or to protect from pressure. These bursas which develop after birth in unusual locations have been called adventitious bursas (fig. 1). A clearer understanding of the changes taking place in the tissues during the formation of such adventitious bursas will help the physician to appreciate the changes of connective tissue in response to unusual functional demands in all parts of the body. The adaptation of the tissues about transplanted tendons and where an attempt is made to regain articular motion is partially the formation of a number of such adventitious bursas.[5] The description of the clinical and histologic development of these bursas is the purpose of this paper.

Before the embryologic studies of Hagen-Torn,[6] it was believed that all bursas were lined with endothelium.[7] But the careful histologic studies of Hammar[7] and of Redderer[8] have demonstrated that the synovial lining both of joints and of bursas is only a special arrangement and modification of connective tissue cells.[9] This adaptation of the lining membrane of the cavity has been carried out to a greater degree in joints which have proceeded through a slower and more elaborate embryologic development than have bursas. All bursas, both the normally occurring and the adventitious ones, vary greatly in the completeness of the adaptation

1. Cunningham, D. J.: Textbook of Anatomy, ed. 5, New York, William Wood & Company, 1923.

2. Bize, M.: Recherches sur les bourses muqueuses perotuliennes, J. de l'anat. et physiol. **32**:85, 1896.

3. Albinus, B. S.: Historia musculorum hominis, Leido Batavorum, T. Haak et H. Mulhovius, 1734.

4. MacDonald, H. K.: Bursitis, Canad. M. A. J. **40**:573, 1929.

5. Campbell, W. C.: Surgery of the Hip Joint from the Physiologic Aspect, Surgery **7**:165, 1940.

6. Hagen-Torn, O.: Entwicklung und Bau der Synovialmembranen, Arch. f. mikr. Anat. **21**:591, 1882.

7. Hammar, A.: Ueber die feineren Bau der Gelenke, Arch. f. mikr. Anat. **43**:266, 1894.

8. Redderer, E.: Sur le development morphologique et histologique des bourses muqueuses, J. de l'anat. et physiol. **32**:25, 1896.

9. Key, J. A., in Cowdry, E. V.: Special Cytology, ed. 2, New York, Paul B. Hoeber, Inc., 1932, p. 737.

of the inner lining of the bursal wall.[10] Some bursal cavities have a definite synovial membrane with cells like epithelial cells; others show somewhat flattened, undifferentiated connective tissue cells. More readily in the bursa of more undifferentiated connective tissue, but in that with true synovial membrane as well, regeneration of the lining membrane can take place after injury or after removal of the bursa.[11] This regeneration of the living cells takes place only if there are movement and intermittent pressure; without these obliteration of the bursal cavity occurs.[12]

Many studies have been made on normally appearing bursas which have been removed because of irritation or infection. The embryologic development of normal bursas, particularly those found about the shoulder joint, has been studied by Redderer [8] and more recently by Simon [13] and by Black.[14] In the human embryo the first sign of the developing bursa is a decrease in the number of fibrils in the primordial connective tissue. There occur a flattening and a conden-

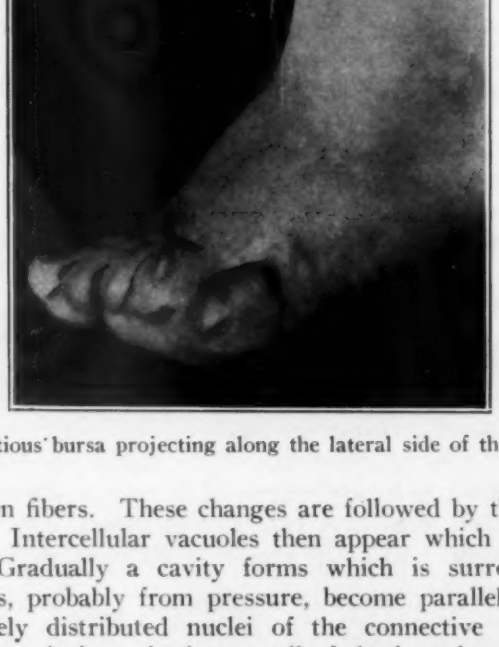

Fig. 1.—Large adventitious bursa projecting along the lateral side of the fifth metatarsal bone.

sation of the collagen fibers. These changes are followed by the appearance of an intercellular space. Intercellular vacuoles then appear which suggest liquefaction within the cells. Gradually a cavity forms which is surrounded by collagen fibers. These fibers, probably from pressure, become parallel to the wall of the cavity. The sparsely distributed nuclei of the connective tissue cells become ovoid and later flattened along the inner wall of the bursal cavity.

With movement of the embryonic limbs, the bursa becomes more clearly defined. The wall, which at first is relatively thin, becomes thicker, and the inner lining takes on more of the appearance of a synovial membrane. Fetal movement

10. Cherry, J. H., and Ghormley, R. K.: Bursa and Ganglion, Am. J. Surg. **52**:319, 1941.

11. Key, J. A.: The Reformation of Synovial Membrane in the Knees of Rabbits After Synovectomy, J. Bone & Joint Surg. **7**:793, 1925.

12. Burrows, H. J.: Bursae and Ganglia, Practitioner **148**:50, 1942.

13. Simon, S.: Ueber Schleimbeutelformes am Schultergelenke des Menschen, Ztschr. f. d. ges. Anat. **81**:369, 1926.

14. Black, M.: Prenatal Incidence Structure and Development of Some Human Synovial Bursae, Anat. Rec. **60**:333, 1934.

is probably not essential for the formation of the bursa, but it is doubtful whether the latter ever attains full development without the stimulus of pressure and movement.[15] With movement, the connective tissue cells and the collagen fibers become arranged in the bursal wall and the secretion of mucin, or mucin-like substances, is initiated. With pressure, the wall thickens. Through normal growth or by the formation of adhesions the bursal cavity often becomes multilocular. Large bursas usually consist of a number of divided cavities.[16]

This manner of development has been observed for the bursas which are present at birth. While little study has been made of adventitious bursas, many theories and much speculation have appeared, connected with their formation. Virchow [17] and many subsequent investigators [18] have expressed the belief that trauma or severe irritation leads to necrosis and liquefaction of the connective tissue and that the bursal wall is a secondary formation about the fluid. Such proteolytic digestion and liquefaction of tissues [19] do take place at times, after injury, but no bursal formation is observed. Schuchardt [20] taught that adventitious bursas represented merely inflammatory production of cystic new tissue. Their relationship [21] to ganglions both in mode of formation and in histologic structure has been mentioned frequently. They have been confused with lymphatic hygroma [22] and have been regarded as dilatations of existing lymphatic channels. Interfascial hemorrhages which do not absorb have been mentioned as possible precursors of bursas.[23]

Attempts to produce adventitious bursas in laboratory animals have been entirely unsuccessful. The application of mild constant pressure on the skin overlying bony prominences in rats or rabbits has invariably led to necrosis of the tissues if sufficiently long continued, never to bursal formation. Intermittent pressure cannot be applied to exactly the same area nor can the pressure be repeated often enough to stimulate the formation of a bursa except in horses, which have shown adventitious bursas under badly fitting collars and saddles. Injections of bland oily substances which were not absorbed have given the temporary appearance of bursal cavities with formed walls; but these cavities were soon replaced by scar tissue, and no true bursal wall was formed.

The formation of adventitious bursas can best be observed in human beings who continue to wear badly fitting shoes or improperly adjusted apparatus. In a clinic largely devoted to disabilities of the feet, an excellent opportunity was provided for the study of adventitious bursas in all stages of development from slight redness and thickening of the skin to the completely formed bursa with its complications of infection, hemorrhage and intrabursal osteocartilaginous bodies. Removal of tissue at operations for the correction of disabilities of the feet permitted histologic examination of a number of these bursas, which provided correlation with the clinical observations. The histologic observations of this study

15. Domeny, P.: Entwicklung und Bau der Bursae mucosae, Arch. f. Anat. u. Physiol., 1897, p. 295.

16. Martin, B.: Ueber künstliche und erworbene Schleimbeutel und ihre Beziehungen zu den Gelenken, Arch. f. klin. Chir. **120**:281, 1922.

17. Virchow, R.: Die krankhaften Geschwülste, Berlin, A. Hirschwald, 1863.

18. Ricker, G.: Die Verflussigung der Bindewebsfasern zugleich ein Beitrag zur Kenntnis der fibrinoiden Degeneration, Virchows Arch. f. path. Anat. **163**:44, 1900.

19. Wells, H. G.: Chemical Pathology, Philadelphia, W. B. Saunders Company, 1920.

20. Schuchardt, K.: Ueber die Entstehung der subcutanen Hygrome, Arch. f. klin. Chir. **40**:606, 1890.

21. Carp, L., and Stout, A. P.: A Study of Ganglion, Surg., Gynec. & Obst. **47**:410, 1928.

22. Tow, A.: Cystic Hygroma in Infancy, Arch. Pediat. **58**:73, 1941.

23. Sorrel, E.: Hygroma hémorrhagique de la bourse séreuse du psoas, Bull. et mém. Soc. nat. de chir. **55**:98, 1929.

were then compared with those from the further study of a large number of specimens of pathologic bursas and ganglions at the Boston Children's Hospital.

Clinical observations have shown that the formation of an adventitious bursa or the occurrence of irritating movement particularly over a bony prominence is dependent on oft-repeated mild pressure. Severe pressure applied once or constant pressure leads to hemorrhage or to necrosis of the tissues. The pressure or the irritation must be insufficient for the death of the tissue and must be often repeated for a long time for the development of a bursa, which is a relatively slow process. On the foot one first sees persisting redness of the skin, which is soon followed by callus. Beneath this callus a bursa is beginning to form, but it cannot be recognized in the tissues at this time. The palpation of a bursa is not possible for several weeks, and often the bursa cannot be found for several months. Continued irritation leads to an accumulation of fluid in the bursal cavity,[24] and this makes palpation easier.

Histologic study of tissues removed at operations in areas where adventitious bursas were developing or had fully developed permitted observation of the various stages in the formation of the adventitious bursa. The first change observed in the subcuticular connective tissue was a localized thickening of the relatively loose areolar tissue, similar to a mild inflammatory reaction but without leukocytic infiltration. Following this early response, the connective tissue fibers assumed instead of the usual irregular arrangement a position parallel to the pressure exerted on the skin (fig. 2). These bundles of connective tissue fibers gradually showed a flattened, wall-like surface which at first was only several cells thick but became thicker under continued pressure. In the surrounding fatty and areolar tissue hemorrhage and edema were often observed.[25] After this stage, a cavity containing fluid began to appear.

In this cavity there was always one parallel fissure with several radiating fissures. As these fissures enlarged, a bursal cavity was formed. Adventitious bursas were never seen developing in preformed spaces in the connective tissue.[26] Martin [27] observed that connective tissue loses its elasticity and tears readily when subjected to repeated trauma. A bursal cavity could occur in such tears in connective tissue fibers, but it is more probable that the bursal wall forms about an accumulation of fluid beneath the area of pressure. The connective tissue cells subjected to irritation frequently show vacuoles suggesting secretory activity.

Whether the fluid which is found at first in an adventitious bursa is tissue fluid or whether it contains mucin from the beginning is difficult to determine.[28] Tests have shown the presence of a mucin-like substance in the fluid of the adventitious bursa at all stages in which examination was made. This suggests that a mucin-like substance appears fairly early in bursal development. Mucin, a compound protein with conjoined sulfuric acid,[29] is found in the body chiefly in two locations: on the surface of epithelial cells, as a secretion, and in the interstices of connective tissue. Mucin and related compounds provide the viscosity and lubricating action of the bursal fluid. This bursal fluid contains in addition to the

24. Tubby, A. H.: Clinical Lecture on Chronic Enlargement of Bursae, Clin. J. **15**:313, 1899.

25. Toussaint, H.: Exostoses mobiles et bursite traumatique de la patte d'oie, Rev. d'orthop. **6**:53, 1905.

26. Anderson, W. S.: A Study of the Normal and Pathological Conditions of the Bursae of the Neck with Special Reference to the Subhyoid Bursa, Am. J. M. Sc. **127**:439, 1904.

27. Martin, B.: Ueber Spalt und Höhlenbildung primäre Höhlraumbildung oder Gewebsverflussigung, Virchows Arch. f. path. Anat. **228**:384, 1920.

28. Mommsen, E.: Zwei Fälle gutartiger grosser Schleimbeutelhygrome, Deutsche med. Wchnschr. **20**:107, 1894.

29. Levene, P. A., and Lópeze-Suárez, J.: Mucins and Mucoids, J. Biol. Chem. **36**:105, 1918.

mucin-like substance a small amount of protein and salts which probably come as a dialysate from the capillaries surrounding the bursa.[30]

It is believed that all connective tissue cells can produce mucin under the appropriate functional stimulus. Garrault [31] observed that all tissue originating from mesenchyme was characterized by the ability to elaborate intracellular sub-

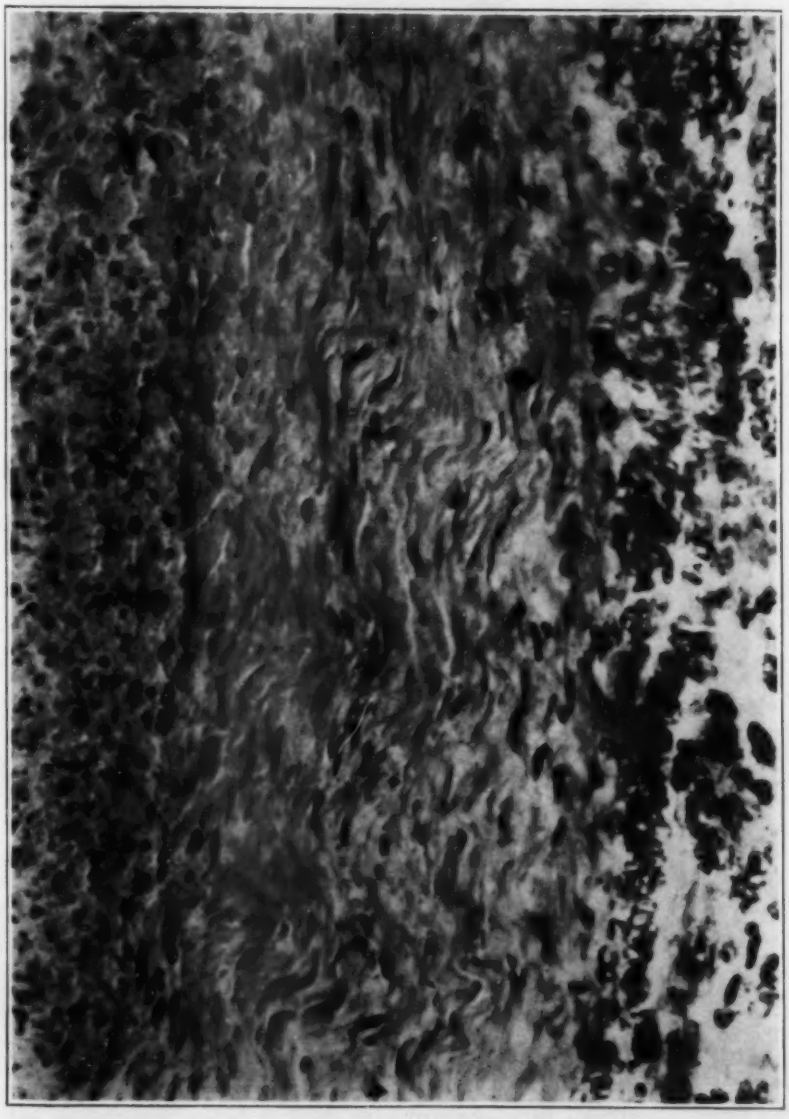

Fig. 2.—Photomicrograph of the tissues beneath a callus on a foot; × 622. There is hemorrhage in the superficial tissues. The connective tissue cells and the collagen fibers are flattened and arranged in parallel bundles. In two central areas with loose intercellular material are the antecedents for bursal formation.

30. Ropes, M. W.; Bennett, G. A., and Bauer, W. A.: Origin and Nature of Normal Synovial Fluid, J. Clin. Investigation **18**:351, 1939.

31. Garrault, H.: Étude histochimique de quelques tissues conjunctifs muqueux, Arch. d'anat. micr. **30**:6, 1934.

stances into a viscous jelly-like compound. In the neighborhood of certain rapidly growing tumors a liquefaction of connective tissue, the so-called mucoid degeneration, is observed. This is interpreted to be a reversion to the fetal type of tissue with the response which is characteristic of fetal tissues.[19]

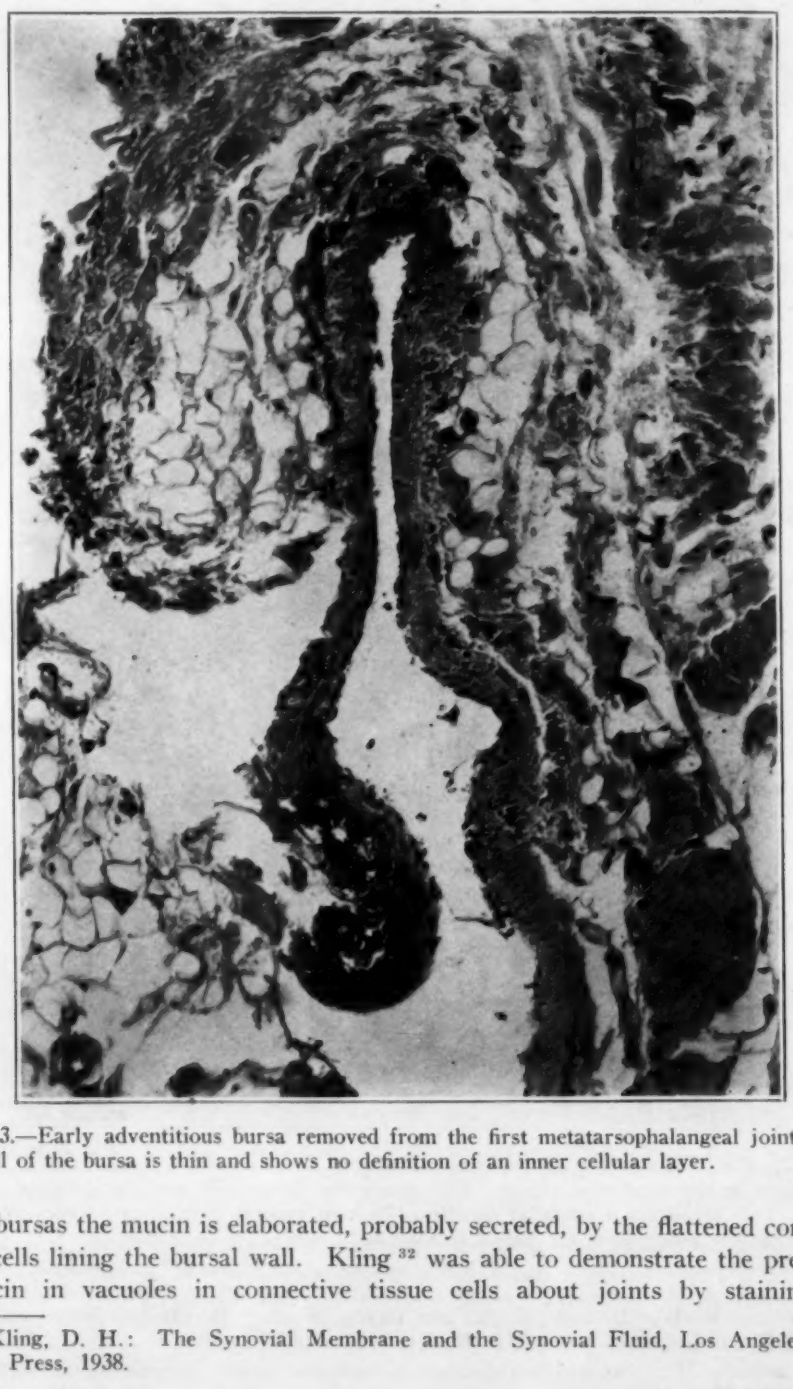

Fig. 3.—Early adventitious bursa removed from the first metatarsophalangeal joint; × 222. The wall of the bursa is thin and shows no definition of an inner cellular layer.

In bursas the mucin is elaborated, probably secreted, by the flattened connective tissue cells lining the bursal wall. Kling [32] was able to demonstrate the precursors of mucin in vacuoles in connective tissue cells about joints by staining with

32. Kling, D. H.: The Synovial Membrane and the Synovial Fluid, Los Angeles, Calif., Medical Press, 1938.

toluidine blue. From cultures of synovial membrane Vaubel [33] concluded that the cells of the synovial membrane have developed the ability to form a synovial fluid and mucin to a special degree and that they differ greatly from other connective tissue cells.

After an adventitious bursa has formed, it is subject to the same pathologic changes that occur in the normally appearing bursa. As the bursal wall becomes thicker, villous formation begins.[34] This greatly increases the secreting surface of the bursa. The lining membrane of the bursa may eventually become a true synovial membrane, but this degree of development in an adventitious bursa is not commonly seen.[35] Infection is relatively common in adventitious bursas, especially in those of the hands and feet, where trauma often occurs. This infection is rarely virulent and seldom is followed by a serious systemic reaction.[36] In the presence of infection there may be a slight purulent discharge. Following such infections, the bursal cavity is occasionally obliterated and is gradually replaced by scar tissue. Great enlargement of an adventitious bursa may occur with persistent irritation and trauma.[37] One patient had a bunion over the first metatarsophalangeal joint which, through prolonged irritation, enlarged until it covered the entire lateral and inferior surface of the great toe. Rupture of a bursa is uncommon. In certain locations where enlargement of a bursa is difficult because of its ligamentous attachments, thickening and infolding of the bursal wall may occur (fig. 4).

Less common pathologic involvements are tumor formation and tuberculous infection. Synovial sarcoma is described in bursas by Berger.[38] There are two types, one arising from ordinary fibrous tissue and the other from more differentiated synovial cells with reticulohistiocytic meshwork.[39] Xanthoma-like growths have been found in bursas by Jaffe, Lichtenstein and Sutro,[40] who considered them to be inflammatory rather than neoplastic in nature. With long irritation as well as with chronic infection, osteocartilaginous bodies may form in bursas.[41] They arise by metaplasia of cells or in an attempt at repair [42] by cells in the villi of the bursal walls (fig. 5). Tuberculous infection in bursas has been described by Wassersug [43] and syphilitic infection by Churchman.[44]

Subcutaneous connective tissue will produce an adventitious bursa under the stimulus of repeated mild trauma, and the removal of that repeated trauma will often lead to regression and sometimes to complete disappearance of the bursa.

33. Vaubel, E.: Form and Function of Synovial Cells in Tissue Cultures, J. Exper. Med. **58**:63, 1933.

34. Fisher, A. G. T.: Chronic (Non-Tuberculous) Arthritis, New York, The Macmillan Company, 1929.

35. Jones, H. T.: Cystic Bursal Hygromas, J. Bone & Joint Surg. **12**:43, 1930.

36. Pick, H.: Zur Frage der Infektiosität der Schleimbeutel beim Hallux valgus, Zentralbl. f. Chir. **54**:70, 1927.

37. Broster, L. R.: Bursitis, Brit. M. J. **2**:1006, 1929.

38. Berger, L.: Synovial Sarcoma in Serous Bursal and Tendon Sheaths, Am. J. Cancer **34**:501, 1938.

39. Franceschini, P.: Richerche istologische sulle articolozioni, Arch. ital. di anat. e di embriol. **27**:76,1929.

40. Jaffe, H. L.; Lichtenstein, L., and Sutro, C. J.: Pigmented Villonodular Synovitis, Bursitis and Tenosynovitis, Arch. Path. **31**:731 (June) 1941.

41. Ettorre, E.: Ueber die Bildung von freien Körpern bei Exostosis bursata, Ztschr. f. orthop. Chir. **50**:113, 1929.

42. Schwarz, E.: Untersuchungen über die Entstehung der Zotten und Reiskörper in Hygromen, Deutsche Ztschr. f. Chir. **235**:140, 1932.

43. Wassersug, J. D.: Tuberculosis of the Greater Trochanter and the Trochanteric Bursae, J. Bone & Joint Surg. **22**:1075, 1940.

44. Churchman, J. W.: Luetic Bursopathy of Verneuil, Am. J. M. Sc. **138**:171, 1909.

This is observed best in small bursas such as those which form superficially about the foot.[45] Here with removal of the irritation the bursa becomes smaller, and finally no further evidence of it can be found. In the thick-walled larger bursas complete obliteration is rarely seen. But with removal of the traumatic stimulus nature will attempt to remove a structure that is no longer required. Week by

Fig. 4.—Very old bursal wall which has been chronically infected; × 311. The wall is very thick and shows fissure formation. The bursa is limited by flattened connective tissue cells.

week one can see a gradual decrease in the size of the bursa. In several months often no bursa can be palpated. But a thickening of the tissues in the bursal area can usually be felt for an indefinite period. If pressure and irritation

45. Galland, W. I.: Operative Treatment of Corns, J. A. M. A. **100**:880 (March 25) 1933.

are again exerted over the area for several weeks, the bursa reappears and will soon return to its former size.

The histologic study of the involved tissues during the subsidence of an adventitious bursa shows the reverse of the process which is observed in its formation. The fluid in the bursa is gradually absorbed. The bursal wall becomes

Fig. 5.—Old adventitious bursa removed from the inner side of a foot; × 266. There are villous formation and the beginning of a loose body from coagulum and cellular detritus. The lining cells simulate a true synovial membrane.

thinner; adhesions form between the two sides. This process is sometimes hastened by hemorrhage.[46] Hemorrhage or severe trauma is followed sometimes

46. Hayward: Chirurgisches Konsilium, Med. Klin. **27**:1759, 1931.

by calcification in the bursal wall.[47] The final stage will show only a thickening of the connective tissue, similar to a scar, in the area where the bursa has been. Occasionally this process of fibrosis [48] proceeds so irregularly that it leads to a chronically painful area.

Many attempts have been made to hasten the natural process of regression in adventitious bursas. Aspiration [49] with or without subsequent pressure over the area has been of little help in causing the bursa to disappear more rapidly. Rapid obliteration of the cavity comes only with destruction of the lining cells.[50] The simplest and most effective method is that of complete removal of the bursa. This is the treatment of choice at the elbow and the knee, where slow regression of the bursa would frequently interfere with normal use of the limb.[51] With the smaller adventitious bursa, the removal of the irritation or the pressure will usually lead to rapid relief of the symptoms [52] and to slower but complete disappearance of the bursa.

SUMMARY

Adventitious bursas are frequently observed in subcutaneous tissues that are subjected to repeated pressure or friction. The development of these bursas is similar to the embryonic development of the normally appearing bursas. There is condensation of the subcutaneous connective tissue followed by the development of a fluid-containing cavity. True synovial lining is not often found in adventitious bursas. A mucin-like substance is found early in the development of the bursas. It is apparently produced by the connective tissue cells lining the bursal cavity. The same pathologic changes which are found in the normally occurring bursa are seen in the adventitious bursa: infection, enlargement, tumor formation and fibrosis. With removal of the irritating stimulus, regression of the bursa is observed. Complete spontaneous disappearance of the smaller adventitious bursas often takes place. The larger bursas usually require surgical removal.

47. Pohl, R.: Zur Ruckbildung von Kalkeinlagerungen in Schleimbeutel, Wien. klin. Wchnschr. **43**:1397, 1930.

48. Morris, M.: Clinical Notes on a Case of Fibroid Disease of Bursae, Brit. M. J. **1**: 867, 1917.

49. Pass, H. R., and Schüller, J.: Entstehung riesiger cystischer Tumoren durch Schleimbeutelruptur, Zentralbl. f. Chir. **57**:2425, 1930.

50. Sarma, P. J.: The Injection Treatment of Ganglions and Bursae: Indications and Limitations, S. Clin. North America **20**:135, 1940.

51. Reder, F.: Inflammation of the Prepatellar Bursa, S. Clin. North America **5**:1289, 1925.

52. Saxl, A.: Wie werden Schleimbeutelentzündungen des Fusses orthopädisch behandelt? Wien. klin. Wchnschr. **48**:929, 1935.

FRACTURE OF THE SHAFTS OF BOTH BONES OF THE LOWER HALF OF THE LEG

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The main objectives in the treatment of a fracture are (1) the best possible end result and (2) the shortest period of disability consistent with such a result. The chief concern of the community at large and also of the patient is how long he will be disabled. Even in cases in which wage earning is not involved, as in those of school children, housewives, and aged persons, confinement and dependence on others are considerations of the first importance. The literature and hospital records are conspicuously lacking in data on when patients return to work or resume useful occupations.

Fracture of both the tibia and the fibula has become increasingly common with the development of the machine age, constituting 8 per cent of the fractures for which patients have been admitted to one representative municipal hospital. It is also one of the most disabling common injuries. Fracture of the shaft constitutes the majority of the fractures of the bones of the lower half of the leg and is selected for discussion.

The patients treated for fracture of the tibia and the fibula in Lincoln Hospital (Department of Hospitals, New York) during the three year period 1939-1941 inclusive numbered 176. Of these, 9 died, a mortality of 5.1 per cent.[1]

The series whose cases are reported here is composed largely of those patients from the group just mentioned whom we were able to follow, plus a similar group from the French Hospital and from private practice. A fairly typical cross section of the metropolitan population is represented. Children under 5 years are not included, as they can scarcely be considered from the point of view of disability.

A trend toward skeletal traction has been apparent during the past ten years. The use of pins and wires has developed in spite of some reluctance to accept the principle of the puncturing of skin and healthy bone. Traction through the calcaneus was later followed by distraction with pins drilled through both fragments and incorporated in plaster. Good results have been reported by Anderson,[2] Curry and Taylor,[3] Griswold[4] and others. Patients are ambulatory, hospitalization is shortened, and retention of fragments is efficient. There is danger, however, of nonunion from separation of fragments. Infection of bone from skeletal traction does occur but seems to be rare.

1. These figures are taken from an unpublished report of the record room of the Lincoln Hospital.

2. Anderson, R.: An Automatic Method of Treatment for Fracture of the Tibia and Fibula, Surg., Gynec. & Obst. **58**:530-646 (March) 1934.

3. Curry, G. J., and Taylor, E. S.: Fractures of Both Bones of Leg: Management by Use of Double Steel Pin Traction in Plaster of Paris, Arch. Surg. **36**:858-866 (May) 1938; correction, ibid. **37**:352 (Aug.) 1938.

4. Griswold, R. A.: Fracture of Both Bones of Leg: Treatment by Modified Boehler Method with New Apparatus, J. A. M. A. **104**:35-40 (Jan. 5) 1935.

Open reduction with internal fixation has been advocated particularly for spiral and oblique tibial fractures. The difficulty of maintaining reduction of these most common fractures of the bones in the lower half of the leg is proverbial. The

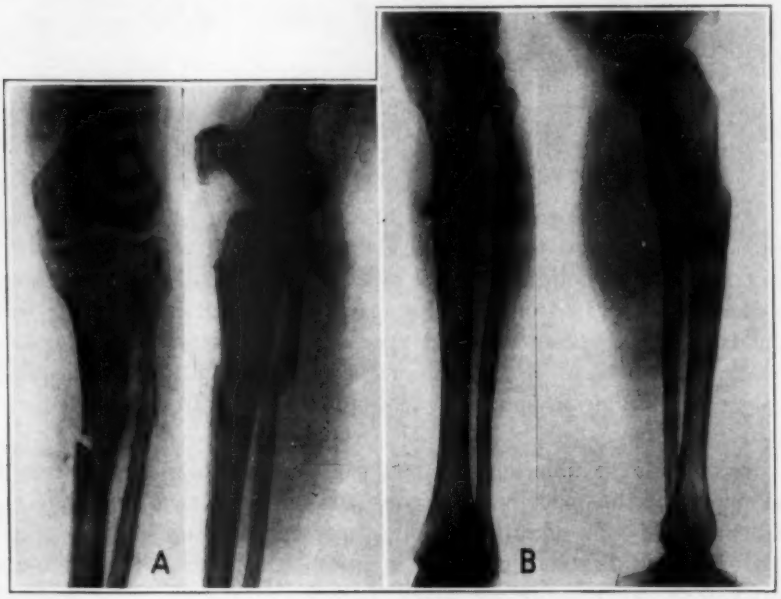

Fig. 1 (case 19).—*A*, tibia and fibula showing comminuted fracture in February 1939. *B*, same bones in November 1942. The fibular fragment and the free fragment of the tibia are united. There is fibrous union of the upper tibial fragment.

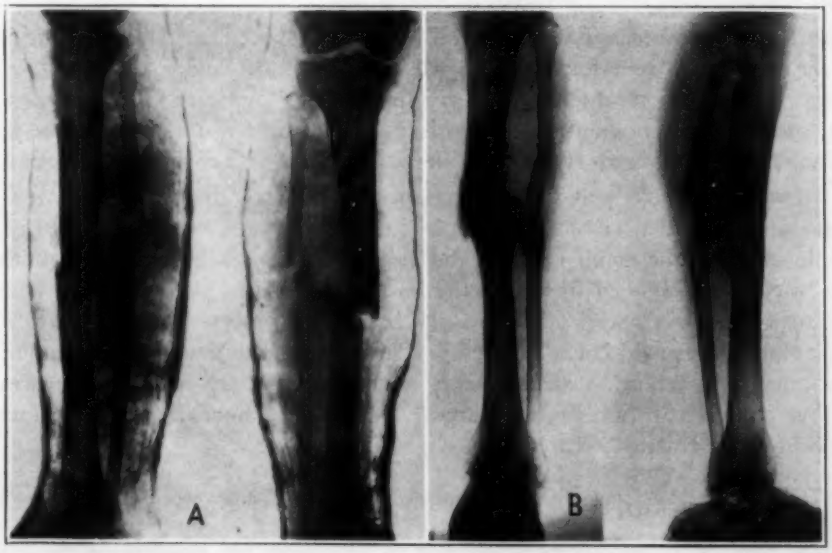

Fig. 2 (case 24).—*A*, marked comminution in August 1940. *B*, abundant callus and apparent cross union in October 1942.

problem of treating them by other means has not yet been solved. The frequency of nonunion and the accessibility of the shaft of the tibia are two of the considera-

tions in favor of open reduction. Mansfield [5] expressed the view that these fractures constitute a clinical entity and reported that the period of hospitalization and the period of disability were greatly reduced following immediate wiring. Closed methods seem to be still favored by the majority, however.

A modification of closed reduction has been used, with encouraging results. Two pins are introduced into each fragment if the fracture is not too near the end of the bone, and an adjustable side bar is used for fixation. The use of plaster

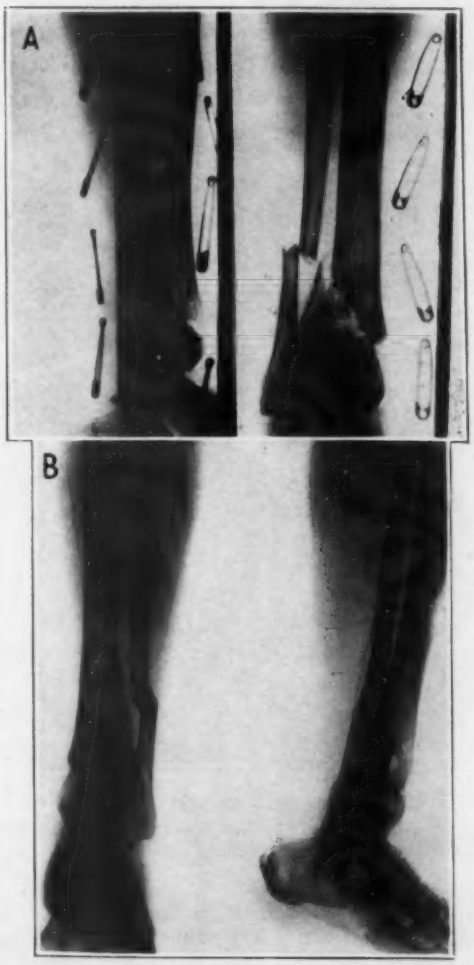

Fig. 3 (case 13).—*A*, lateral displacement and marked comminution in February 1941. *B*, good alinement and firm union in October 1942.

can be eliminated by this means, and much interest has recently been focused on the principles involved.[6]

5. Mansfield, R. D.: Treatment of Oblique Spiral Fractures of Both Bones of the Leg: Analysis of 15 Cases Treated by Open and Closed Methods, J. Bone & Joint Surg. **23**:910-916 (Oct.) 1941.

6. Bradford, C., and Wilson, P. D.: Mechanical Skeletal Fixation in War Surgery, Surg., Gynec. & Obst. **75**:468-476 (Oct.) 1942. Lewis, K. M.; Breidenbach, L., and Stader, O.: The Stader Reduction Splint, Ann. Surg. **116**:623-636 (Oct.) 1942.

In our series of 32 cases manipulation with plaster immobilization was used only nine times. The group thus treated included all but one of the youngest patients, and most of the shortest periods of disability were recorded for this group. The brevity of the periods of disability is obviously due to the adaptability of growing bones and to the lack of gross deformity in the patients so treated.

Recumbency with Kirschner wire traction through the calcaneus was used in 17 cases, or a little more than 50 per cent. The wire was left in place on an average of nearly four weeks and was replaced by plaster splints when union was firm enough or was incorporated in plaster for ambulatory treatment. Compounding or associated injuries, including shock, were present in 10 of these cases. Many of the longest periods of disability and poorest results were found in this group comprising the most seriously injured patients.

Fig. 4 (case 1).—*A*, technical error in the reduction of a fracture in June 1937. Such errors are still seen occasionally. *B*, same bones in November 1942. Any benefit from this operation was probably due to stimulation from the drill hole.

Among those of particular interest was a 54 year old housewife, injured in an automobile accident, with multiple fractures of rib and injury of the head besides the fractures of the bones in her leg. Although she had fibrous union only of the tibia (fig. 1), she considered herself no longer disabled at the end of one year and showed good function of the knee and the ankle. There were outbowing and limp (case 19 in table).

A 50 year old laborer, also the victim of an automobile accident, sustained a compound fracture of the bones in the lower half of the right leg, with a persistent draining sinus (fig. 2). The cross union shown in figure 2 *B* has rarely been encountered in our experience but is of little clinical significance. In spite of complications, the patient after ten months walked with slight limp and did light work, though he was not able to continue steadily (case 24).

A 56 year old laborer fell and sustained a badly comminuted fracture of the lower third of the tibia and the fibula of the left leg (fig. 3). His convalescence was complicated by serious phlebitis and pulmonary infarction. The course of illness was stormy, and the patient was still disabled one and a half years after the accident, though union was firm and weight bearing with a bandage was fair (case 13).

Open reduction was performed six times.

A 37 year old Negro woman sustained an oblique fracture of the middle and lower thirds of the right tibia (fig. 4). She had asthma with cardiac complications. An attempt was made to fix the fragments with a single screw, a violation, admittedly, of the principles of internal fixation. Although some shortening and angulation occurred, the bones showed firm union and good functional result after seven months' disability (case 1).

A 34 year old saleslady slipped in the street, sustaining a compound spiral fracture of the lower third of the left tibia, which was immediately operated on (fig. 5). A Parham band

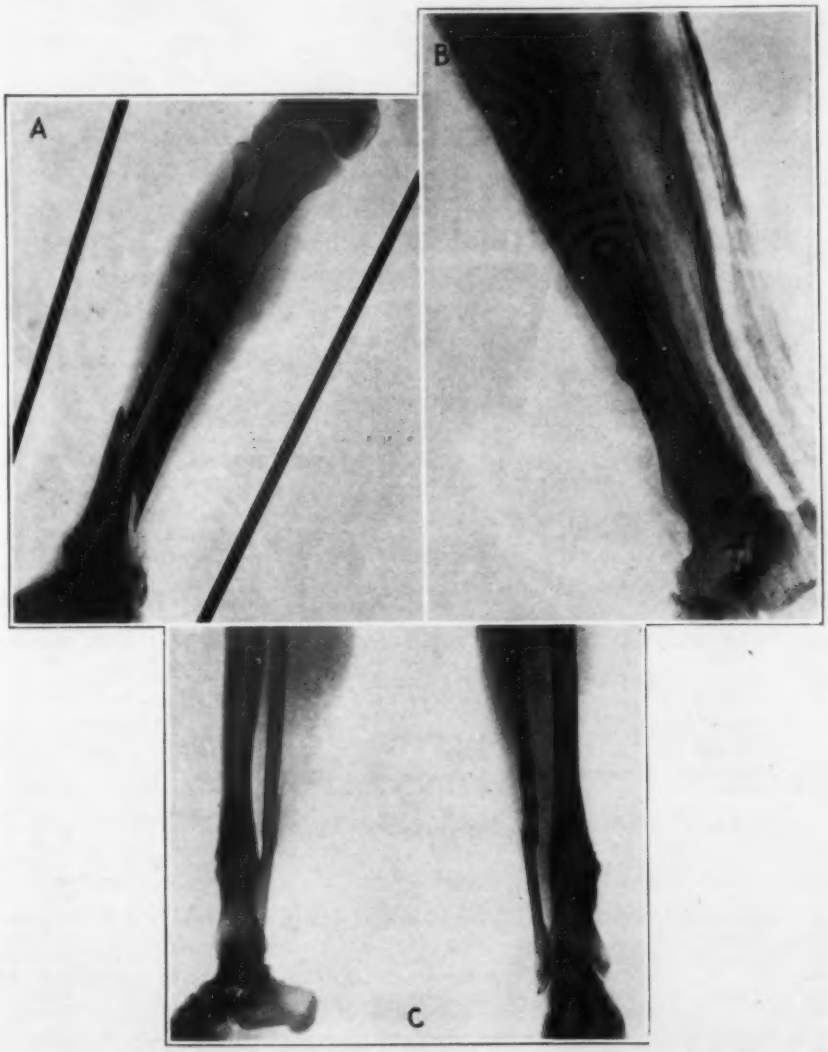

Fig. 5 (case 11).—*A*, typical spiral fracture in February 1941. *B*, Parham band fixation. *C*, same bones in November 1941. The surprising superabundant callus raises the question of incomplete immobilization or foreign body reaction.

was used with accurate reduction, and there was good convalescence with a total of fifteen days' hospitalization. Bony proliferation caused objectionable thickening of the ankle but within seven months she returned to work with good function of the ankle (case 11).

Lane plates were used in the treatment of 2 patients. One had compounding, and a sinus developed, necessitating the removal of the plate after callus was

Analysis of Data on Thirty-Two Patients Treated for Fracture of Both Tibia and Fibula

No.	Age and Sex	Cause	Treatment	Days in Hospital	Complications	Disability	Deformity	S	A	E*	Comment
1	48 F	Fall	Open operation; metal screw	52	Cardiac asthma	7 mo.	Lateral bowing	4	3	4	Clinically good position
2	46 F	Fall	Kirshner wire	60	Congenital dislocation of hip	12 mo.	Swelling	2	3	2	History of hypertension
3	19 M	Automobile accident	Debrided; Kirshner wire	57	Compounding	13 mo.	None	3	4	4	In army after 1 year
4	8 M	Automobile accident	Plaster	42	Compounding	3½ mo.	None	4	4	4	Callus after 15 days
5	68 M	Automobile accident	Kirshner wire	35	.....	4 mo.	Lateral angulation	3	3	3	No limp; does light work
6	10 F	Fall	Plaster	27	.....	2 mo.	.....	4	4	4	
7	5 M	Fall	Plaster	3	.....	4 mo.	.....	4	4	4	
8	75 M	Automobile accident	Kirshner wire	81	Injury of head; diabetes	10 mo.	Swelling, lateral bowing	2	2	3	Good recovery despite age of 75 years
9	6 M	Fall	Plaster	3	.....	7 wk.	.....	4	4	4	
10	13 M	Automobile accident	Plaster	41	Phlebitis; Colles' fracture	3 mo.	.....	4	4	4	
11	5 F	Automobile accident	Plaster	24	.....	7 wk.	.....	4	4	4	
12	13 M	Fall	Plaster	12	.....	2½ mo.	.....	4	4	4	
13	56 M	Fall	Kirshner wire	60	Phlebitis	17 mo.	Swelling	2	3	1	Pain; still disabled after 1½ yr.
14	5 F	Automobile accident	Debrided wire	90	Compounding, sloughing	8 mo.	Scar, bowing	4	2	4	Severe injury of bone and soft parts
15	58 M	Jump	Kirshner wire	150	.....	11 mo.	Swelling	4	3	4	Two admissions; occasional pain in heel
16	51 F	Fall	Kirshner wire in plaster	28	.....	3½ mo.	None	4	4	4	Skeletal traction and plaster immobilization combined
17	38 F	Fall	Kirshner wire	34	.....	6 mo.	Anterior bowing	1	2	3	Pain and edema; sedentary occupation
18	44 M	Automobile accident	Plaster	28	Wound of scalp	5 mo.	.....	4	4	4	Standing; elevator operator
19	54 F	Automobile accident	Kirshner wire	45	Fracture of ribs; wound of head; erysipelas	1 yr.	Anterior and lateral bowing	2	2	2	Pain in leg; fibrous union
20	65 F	Automobile accident	Kirshner wire	54	Compounding	2 yr.	Lateral bowing	1	1	1	Pain and limp; disabled
21	55 M	Automobile accident	Kirshner wire	365	Compounding shock; fracture of arm	4 yr.	Shortening	1	1	0	Clinically good union; sequestration
22	21 M	Fall	Kirshner wire	65	Compounding	1 yr.	None	3	3	3	Discharged after 2 mo. in army
23	37 F	Fall	Lane plate	63	.....	7½ mo.	Swelling	3	4	3	Some pain; overweight; litigation
24	50 M	Automobile accident	Kirshner wire	48	Compounding	10 mo.	Deformity	3	1	2	Sequestration; still disabled
25	44 M	Fall	Kirshner wire	61	Concussion; pneumonia	8½ mo.	Swelling	3	3	4	Some pain in back and leg
26	57 M	Fall	Plaster Kirshner wire	95	Compounding, osteomyelitis	11 mo.	None	3	3	4	Knee flexes to 90 degrees
27	16 M	Football injury	Plaster	10	.....	2 mo.	None	4	4	4	
28	37 M	Automobile accident	Kirshner wire	43	Concussion	18 mo.	.....	1	1	1	Pain and stiffness; disabled
29	19 M	Football injury	Kirshner wire	27	.....	5 mo.	None	4	4	4	Joined navy 10/22/42
30	67 F	Automobile accident	Open reduction; plaster	96	Compounding; shock; injury of head	9 mo.	Overriding	3	3	3	Improving; wears brace
31	34 F	Fall	Open operation; Parham band	15	.....	7 mo.	Swelling	3	4	4	Overweight; litigation
32	48 M	Automobile accident	Lane plate	111	Compounding; osteomyelitis	14 mo.	Bowing	3	3	3	Disabled; litigation

* In these three columns symptomatic (S), anatomic (A) and economic (E) disability is graded from 1 to 4, with 4 representing the maximum degree.

shown by the roentgenogram. The other had a simple oblique fracture which failed to give a satisfactory reduction with manipulation and plaster. She returned to work with the plate in situ seven and one-half months after injury. Both made good recoveries but were involved in litigation, which frequently is prejudicial to periods of disability.

Silver wires were used in the case of a 5 year old girl who was struck by an automobile, sustaining a badly comminuted fracture of the middle third of the tibia, which sloughed extensively. Removal of the wires became necessary. With a skin graft a good functional result was obtained, thanks to the reparative powers of youth. Weight bearing was begun, and walking without limp, one year after the accident (case 14).

A middle-aged professional woman sustained a compound fracture of the lower third of the right leg, with concussion and injury of the head. Debriding and suture were followed by union in three months; weight bearing and some earning capacity were present at nine months. At the time of writing, fourteen months after the accident, she can stand and walk short distances with a cane and wearing a leg brace (case 30).

Averages and Totals

Average age		36.6 yr.
Average period of disability		5.7 mo.
Average stay in hospital		60.2 days
Cases in which compound fracture was observed		10, or 31.2%
Causes		
Fall	14 cases, or 43.7%	
Automobile accident	15 cases, or 46.9%	
Other mishaps	3 cases, or 9.4%	
Treatment		
Kirschner wire	17 cases, or 53.1%	
Plaster	9 cases, or 28.1%	
Open	6 cases, or 18.8%	

In evaluating these results one notes three fundamental factors becoming increasingly clear:

1. The mental endowment of the patient and the nature of the occupation were of great importance. One patient who failed to return to work was on relief before he was injured, and his general makeup limited the employment available to him. Another, who had his own tailor shop, returned to work after eight months although he had sustained concussion and contracted pneumonia during convalescence.

2. Associated injuries and complications, especially vascular trauma and cardiovascular conditions, prolonged disability and impaired end results.

3. Compensation and medicolegal claims are too well recognized to require further comment. Some of the patients who walked without limp and showed good functional results remained out of work pending settlement of their cases in court or as long as compensation was continued.

SUMMARY AND CONCLUSIONS

Thirty-two cases of fracture of the shafts of the tibia and the fibula in which various methods of treatment were followed are presented.

The periods of disability of those who returned to work averaged five and seven-tenths months.

Marked improvement in methods and in results of treatment has been observed over the last ten years.

Skeletal traction can be used with reasonable safety and with expectation of good results.

Open reduction is indicated in selected cases.

End results are difficult to evaluate, and length of disability is not an accurate index of the efficiency of the method of treatment or of the severity of the injury.

Of the 6 patients who had not returned to work when last seen, 3 have the poorest results recorded—four years, two years and one and one-half years, respectively, after injury. All 3 patients showed bony union, but in 2 there was chronic osteomyelitis.

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DEVELOPMENT OF THE HUMAN KNEE JOINT

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My interest in developmental and acquired pathologic disturbances of the meniscuses of the knee joint prompted me to seek an answer to the variations seen. I was desirous chiefly of learning the origin and time of appearance of the meniscuses and of the synovial membrane and their relationship to one another. The current textbooks and available literature were inadequate and confusing on these points because of widespread disagreement among various authors. The concept of the development of the knee joint varied according to the approach, whether from the point of view of embryology or that of comparative anatomy. The present study is based on embryologic observations and study of human anatomic specimens alone.

COMPARATIVE ANATOMY

In 1887 Sutton [1] explained the origin of the intra-articular structures by the indrawing of extra-articular ligaments with the assumption of ability to flex the joint. The meniscuses were said to be derived from the femorocaudal and associated muscles by the mechanism he suggested.

Certain mammals, such as the beaver, Ungulata, Edentala and Monotremata, have knee joints made up of three compartments, and cavities of this type have been encountered in man.[2] The ligamentum mucosum and the alar ligaments as seen in the usual human specimen are considered to be the remains of the wall separating the patella and the femoral condyles.

The anterior cruciate ligament and the ligamentum mucosum are not separated in the lower monkeys as they are in man.[3] Macacus rhesus has an internal meniscus like that of man, but the external meniscus is continued obliquely across the joint behind the posterior cruciate ligament to the internal femoral condyle. In man the posterior part of the external meniscus is firmly attached to the tibia, but it gives off a structure known as the ligament of Wrisberg, which in turn is attached to the femoral condyle so that the difference between the two species is not very marked. In all joints of the mammalian type the meniscuses are attached to the femurs rather than to the tibias. The added fixation noted in man has been thought to be present in order to bear the added strain of standing with the knees in extension.

The external meniscus of the baboon, the vervet and the spider monkey and of the monotreme is ring shaped while the medial one is crescentic. This configu-

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Read before the Boston Orthopaedic Club, Boston, Feb. 7, 1938, and presented in part at the Clinical Congress of the American College of Surgeons, Boston, in November 1940.

1. Sutton, J. B.: Ligaments: Their Nature and Morphology, Philadelphia, P. Blakiston, Son & Co., 1887.

2. Struthers: Complete Septum in the Femoro-Tibial Part of the Knee Joint, J. Anat. & Physiol., vol. 27, pt. 3, 1893.

3. Parsons, F. G.: The Joints of Mammals Compared with Those of Man, J. Anat. & Physiol. **34**:301 (April) 1900.

ration is also seen rarely in man. Both meniscuses of the long-eared bat (Plecotus) are ring shaped. No meniscuses have been found in those animals whose knees have no power of rotary motion, such as the fruit bat (Cheiroptus).

The most primitive arrangement of meniscuses is that in which both are attached posteriorly to the femur as in the duck mole and the anteater. Other mammals show attachment of the external one to the femur posteriorly and of the internal one to the tibia; however, in man both are fixed posteriorly to the tibia.

In all monkeys and monotremes the superior tibiofibular joint communicates with the knee joint, but this feature is not seen in Insectivora and has not been reported among many types of anomaly seen in man except as stated by Sir Arthur Keith.[4]

LITERATURE

The general lack of detail and the striking variance of opinion are well illustrated by the data presented in the following literature.

In Gray's "Anatomy of the Human Body"[5] it is stated that in several diarthroses the mesoderm between the ends of the bones does not become absorbed completely, a portion persisting and forming articular disks, but no details are available beyond these statements.

Arey[6] stated that the ligaments and the tendons in adult joints represent secondary invasions into the joints covered by reflected synovial membrane and are really external to the articular cavities. He also expressed the belief that the cells on the inner surface of the capsule merely flattened to form what he calls the epithelioid synovial membrane.

Bardeen[7] made the statement that the semilunar disks and the cruciate ligaments are differentiated directly from the blastema. He was unable to demonstrate any evidences of phylogenetic structures discarded during ontogeny.

Keith expressed the opinion that the meniscuses are remnants of the interchondral disks projecting into the gap between the articular surfaces. According to this author, the development of the femoral condyles toward the popliteal space isolates a posterior part of the capsule, which comes to lie within the joint and forms the cruciate ligaments. Occasionally the human knee communicates with the superior tibiofibular joint through the synovial diverticulum beneath the tendon of the popliteus muscle. The exclusion of the fibula takes place, according to Keith, about the eighth week of fetal life. He also made the statement that the articular cavity starts as five separate synovial compartments, which become continuous about the fourth month.

Keith said that all joints are formed by disappearance of cells from the interchondral disk, starting at the periphery, and that the perichondrium gives rise to the capsule. He insisted that the synovial membrane takes origin from the perichondrium and is cartilaginous in nature.

Bardeen stated that the meniscuses and the cruciate ligaments are differentiated directly from the blastema. He recorded the sequence of events as follows: meniscuses, capsule, cruciate ligaments, patella and finally ligamentum mucosum, all being derived from the blastema directly. He says a cavity is first seen between

4. Keith, A.: Human Embryology and Morphology, ed. 5, Baltimore, William Wood & Company, 1933.

5. Gray, H.: Anatomy of the Human Body, ed. 22, revised and reedited by Warren L. Lewis, Philadelphia, Lea & Febiger, 1930.

6. Arey, L. B.: Developmental Anatomy, Philadelphia, W. B. Saunders Company, 1925.

7. Bardeen, C. R.: Human Embryology, Philadelphia, J. B. Lippincott Company, 1910, vol. 1.

the patella and the femur at 30 mm.[8] Lucien recorded the subsequent appearance of four other cavities. Limb buds may be noted toward the end of the third week. Between the fifth and the sixth week definite outlines of the legs are recognizable. By the seventh week all the individual muscles of the adult except the lumbrical ones can be identified.[9]

MATERIAL AND METHOD

Fetuses of varying age groups were obtained from the surrounding hospitals. The embryologic collection of Harvard University was also utilized. In addition, surgical and postmortem specimens from the Children's Hospital were studied. They consisted of meniscuses and synovial membranes from about 50 knee joints varying in age from the eighth fetal month to the twelfth postnatal year.

The knee joints of the collection just mentioned were fixed in Bouin's solution for periods varying from three days to several weeks, as also were the meniscuses and the synovial membranes. They were then dehydrated with alcohols. The larger specimens were embedded in celloidin (a concentrated preparation of pyroxylin) and cleared in oil of Origanum after cutting. The smaller ones were cleared in cedar oil and xylene and embedded in paraffin. Serial sections of some of the joints were made in the coronal plane, while other joints were prepared in sagittal, transverse and oblique planes, respectively. The paraffin sections were 6 to 10 microns, while the celloidin ones were 15 to 20 microns, in thickness. From each group of five slides, two were stained with Mallory's hematoxylin and eosin, and one each with Mallory's phosphotungstic acid–hematoxylin, aniline blue and Foot's reticulum stain, and mounted in gum dammar, in routine fashion.

The embryologic material of the Harvard University collection had already been prepared in the form of serial section. The stains used in these were alum-cochineal and orange G, borax carmine and spirit blue, as well as carmine and iodine green.

Fifty joints representing age periods from the twentieth fetal day to three weeks after birth were studied, and 50 specimens of synovial membranes and meniscuses representing age periods up to the fifth year after birth were added.

DATA

The youngest embryo examined was 20 days of age. At the age of 20 days the caudal limb buds are just appearing and are easily recognized both grossly and microscopically. They are composed of dense homogeneous blastemal tissue.

When the embryo has reached the age of 27 to 30 days, the hindlimb buds are larger but show no differentiation. Blood vessels are to be seen in the depth of the limb buds at 31 to 34 days, and nerve fibers are found growing into the bases of the buds. Definite condensation of the blastemal cells as anlages of the skeletal structures is noted at 38 to 39 days. The anlage of the tibia and the fibula is a single sheet. The femur is well outlined in precartilage form at 47 to 51 days, and chondrification has begun. It is fairly well advanced in the center of the shaft, but less well developed toward the ends. Chondrification of the tibia is fairly well advanced but not as far as that of the femur. The anlages of these two bones have always been separate. The tibia and the fibula are now recognized as having become separate from one another after having arisen as a single sheet of condensed blastema. The perichondrium is well developed and distinct. The interchondral scleroblastemal disk between the femur and the tibia is homogeneous and dense, with no evidence of a joint space. The femur and the tibia are at right angles to one another in the region of the future knee joint. The fibula does not enter into the formation of the knee joint by articulation with the femur except for the brief period of time during which the fibula and the tibia are one blastemal mass, before there is any evidence of a joint space. The foot plate is present at this stage.

8. Bardeen, C. R., and Lewis, W. H.: Development of the Limbs, Body Wall and Back in Man, Am. J. Anat. **1**:1 (Nov. 7) 1901.

9. Bardeen, C. R.: Studies of the Development of the Human Skeleton, Am. J. Anat. **4**:3 (May 25) 1905.

Between 52 and 55 days the process of chondrification is more advanced in the femur and the quadriceps muscle is recognizable. The region of the future knee joint is well demarcated and consists of the scleroblastemal disk between the femur and the tibia as described (fig. 1). The perichondrium still appears as condensed blastemal tissue with no further differentiation. The sciatic and tibial nerves are seen. Chondrification is more fully developed in the tibia and the fibula. There are no tibial spines. The condylar prominence of the distal end of the femur is present. The skeletal structures of the foot plate are seen in precartilage form.

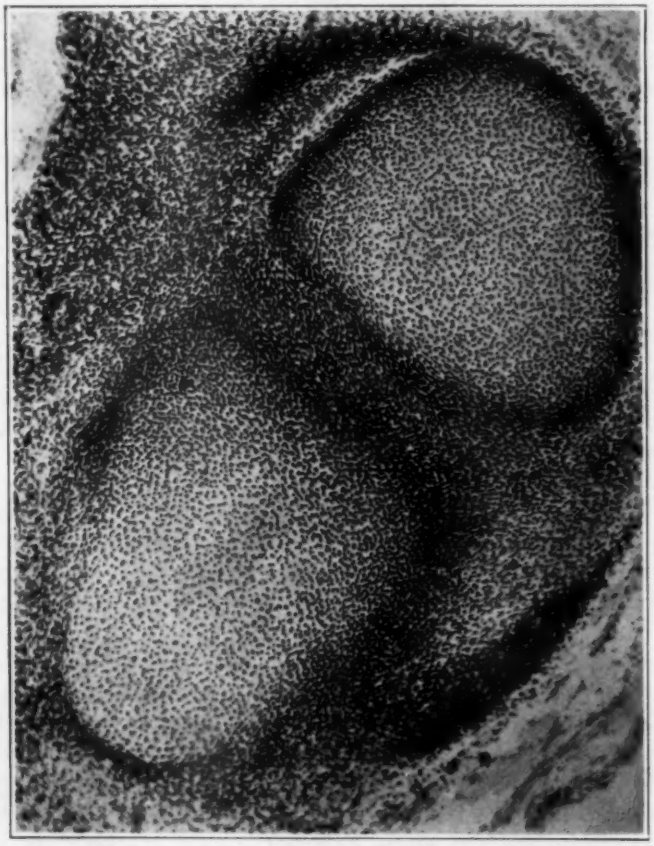

Fig. 1.—Photomicrograph of a transverse section of a knee joint at the fetal age of 52 to 55 days, showing a dense blastemal mass between the femur (upper bone) and the tibia (lower bone) with no evidence of a joint space. Alum-cochineal; × 110.

At the age of 60 days the cartilage is more mature in appearance, with an increase in the amount of matrix. The interchondral disk has begun to show early and small degrees of decreased density and irregular loss of cellular substance anteriorly and posteriorly. These changes appear to be in the nature of a rapid and complete dissolution of the cells in the area without the finding of cells in different stages of disintegration. This loss of substance is the first sign of the formation of the cavity of the knee joint. Condensation of blastema for formation of the patella is noted. The central portion of the interchondral disk remains dense. The posterior curve of the femoral condyles is well developed.

At 8 to 9 weeks the femur, the tibia and the fibula consist of precartilage in the regions close to the knee joint but are composed of more mature cartilage away

from the joint. About all aspects of the bones is a condensation band of mesenchymal cells, forming a definite limiting membrane or perichondrium. In the region of the knee joint the space between the bones is filled by a mass of mesenchymal tissue or blastema which is somewhat less dense than that forming the perichondrium. The cells in the central portion of the joint area are compactly arranged while those at the periphery, although of like appearance, are less compact.

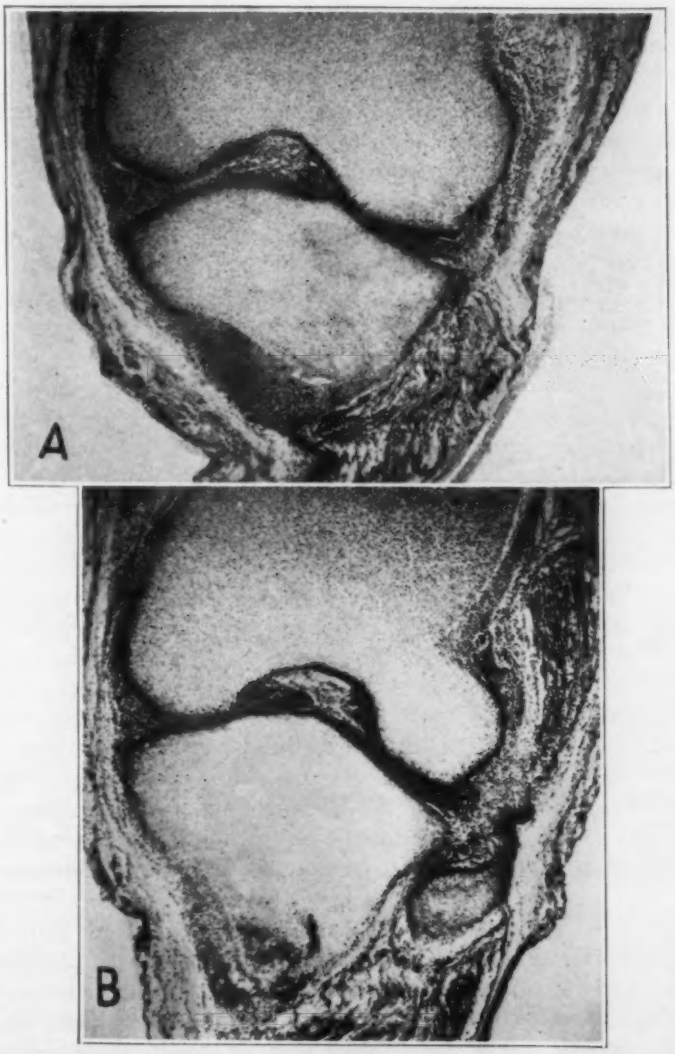

Fig. 2.—*A*, photomicrograph of a coronal section of a knee joint at the fetal age of 8 to 9 weeks, showing the earliest signs of formation of an articular cavity as slits in the dense mesenchymal mass between the femur (above) and the tibia (below). Hematoxylin and eosin; × 28. *B*, photomicrograph of a coronal section of a knee joint at the fetal age of 8 to 9 weeks, showing early joint space as a slit in the mesenchymal tissue above the tibial condyle as well as minute cavities in the central portion of the interchondral disk. Note that the fibula (see to the right of the tibial condyle) does not articulate with the femur. Hematoxylin and eosin; × 28.

Within the mass, toward the periphery, and on either side of the joint area, near the future articulating surfaces of the bones, are four slitlike openings (fig. 2 *A*).

Over the proximal end of the tibia the two distal slits coalesce and the cavity extends across the entire joint area. In the region of the widest portion of the intercondylar notch, there is irregular vacuolation of the mesenchymal mass. There is no evidence of participation of the fibula in the knee joint, and the tibiofibular articulation is poorly demarcated (fig. 2 *B*). The capsule is not yet present. The region of the meniscuses shows the dense arrangement of blastemal cells, but the form is only of broad masses with no actual separation of the parts into definite structures. Condensation of mesenchyma for development of the patella is recognized, and posterior to this is an incompletely developed cavity which does not communicate with the other cavities mentioned.

During the ninth to tenth weeks it is seen that the general contours of the tibia and the fibula are as in the adult except for indefinitely outlined tibial spines. The femoral condyles are better demarcated. The articular margins are composed of more mature cartilage than at eight weeks.

The joint space is quite well demarcated, even in the central portion, into four compartments, viz., one inferior to each femoral condyle, and one superior to each tibial tuberosity. Anteriorly these are separated by a mass of blastemal tissue in which are numerous small cavities of varying size with no definitely demarcated quadriceps pouch. The mass of blastema in the midline of the joint thus acts as a rather complete septum in the anteroposterior direction. The capsule is beginning to appear in the superior half of the joint and stands out prominently as a thin dense band of parallel young fibroblasts continuous with the perichondrium. The cruciate ligaments are easily recognizable as compact masses of wavy strands—young fibroblasts. Both cruciate ligaments are quite separate from each other and can be traced in all directions except at the anterior and the posterior portion of the joint. The meniscuses are well separated from the articular surfaces and consist of very dense crescentic masses of young fibroblasts with attachments to the capsule and the cruciate ligaments as noted in the adult. They are homogeneous throughout. The capsular tissue is less dense than the meniscal masses, and the cruciate ligaments are comparable to the capsule in this respect. In those areas where the meniscuses fuse with the capsular and cruciate ligaments and the superior surface of the tibia, the transition is an almost imperceptible one inasmuch as these structures are composed of tissue in essentially the same embryologic scale of differentiation. There is no well developed synovial membrane. No blood vessels are found except at the periphery of the joint, and as yet they have not penetrated any of the intra-articular structures. The cartilaginous patella has appeared.

At the age of 10 to 11 weeks the articular surfaces show little change from the picture seen in the embryo a week younger. The patella is easily recognized and consists of early cartilage. The articular cavity is somewhat more extensive in that the quadriceps pouch is better demarcated and the complete midline septum shows less prominently. The joint space is now rapidly approaching the shape of a single cavity of irregular outline with disappearance of a greater part of the aforementioned septum by coalescence of the small cavities previously mentioned (fig. 3). The cruciate ligaments and the meniscuses are now more mature in appearance but show no other changes. No blood vessels are seen in the meniscuses, but capillaries are noted in the blastema about the cruciate ligaments.

At the age of 12 weeks the cartilage of the distal end of the femur and the proximal end of the tibia is quite well developed and some bone is beginning to appear in the central portions of the shafts. The joint cavity consists of a large irregular space of essentially the same contour and relative size as seen in the

adult joint.[10] The meniscuses are well developed and crescentic in outline, as mentioned previously. They are attached at the periphery to the capsule, and a suggestion of coronary ligaments is now noted. It consists of a definite decrease in the density of the fibroblastic mass between the periphery of each meniscus and the capsule together with a differentiation in contour which outlines the border of the disk more sharply. In this region capillary blood vessels have penetrated from the capsule but do not appear to have progressed into the meniscus. Each meniscus presents a homogeneous cellular structure of fibroblasts (fig. 4). The tibial spines are recognizable. The cruciate ligaments are prominent and easily distinguished from one another by the direction of their parallel fibers. Surrounding these, the intercondylar notch contains a small amount of loosely arranged but quite well developed fibroblasts. The cavity is not lined by any specialized group or layer of cells. At this stage there appears to be no difference between

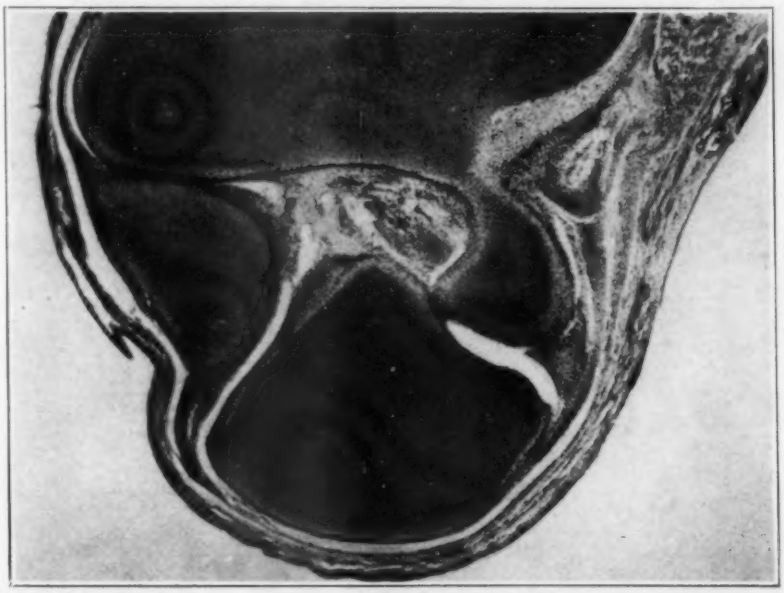

Fig. 3.—Photomicrograph of an oblique section of the knee joint at the fetal age of 10 weeks, showing a meniscus on the right between the femur (above) and the tibia (below), the patella (left) and the extent of the articular cavity. Hematoxylin and eosin; × 28.

the cells covering the articular surfaces of the bones, those of the cruciate ligaments, those of the meniscuses, those of the coronary ligaments and those of the capsule except that the cells of the last two appear as somewhat more fully differentiated fibroblasts, while those of the meniscuses and the cruciate ligaments resemble less completely developed mesenchymal cells. The meniscuses are attached to the central portion of the tibia at their anterior and posterior ends, and are wedge shaped in cross section.

The picture at 12½ weeks shows the articular cartilage somewhat more mature, but it continues to be covered by the cell layer previously described. The cells of the meniscuses, periosteum, capsule, cruciate ligaments and coronary ligaments appear to be better differentiated (fig. 5 *A*). Blood vessels are seen

10. Flint, J. M.: Notes on the Form of the Cavity of the Knee Joint, Bull. Johns Hopkins Hosp. **15**:163 (Oct.) 1904.

in the loose tissue surrounding the cruciate ligaments and in some areas appear to be entering the meniscuses from the coronary ligaments. The ligament of Wrisberg and the ligamentum transversum have not been recognized. The ligamentum mucosum and the alar ligaments have as yet shown no definite outline.

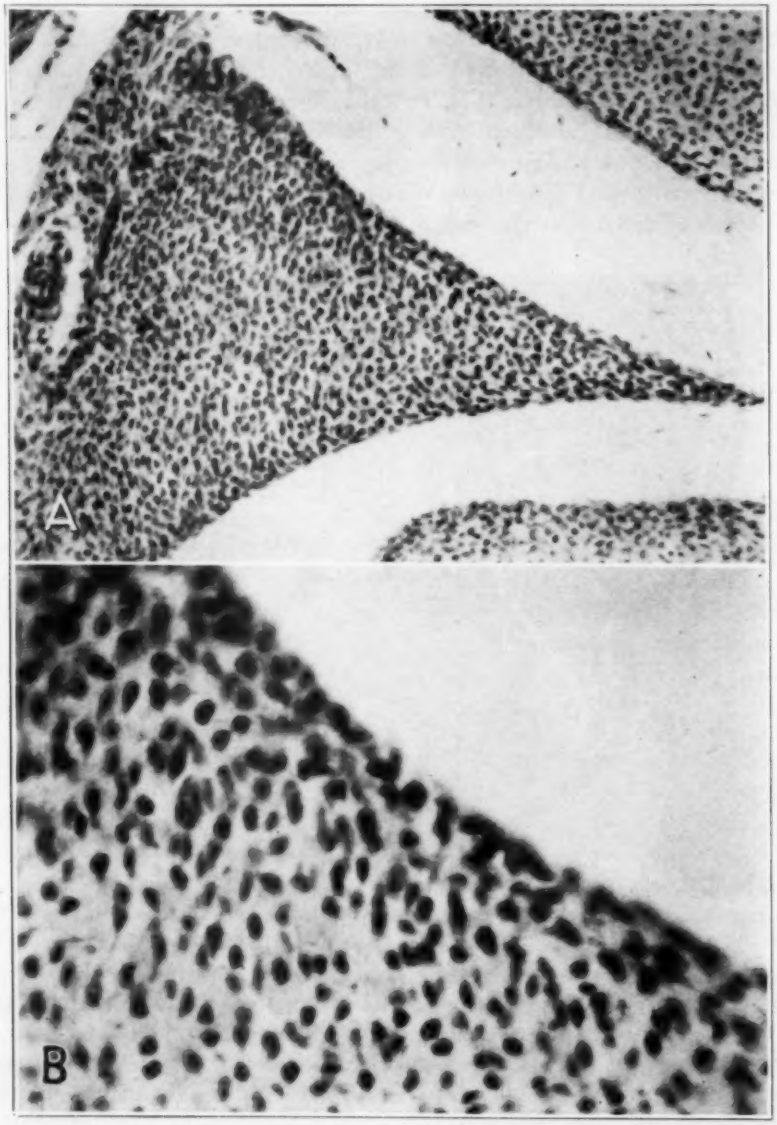

Fig. 4.—*A*, photomicrograph of a meniscus at the fetal age of 12 weeks. No cartilage matrix is present, and the synovial membrane has not made its appearance. Hematoxylin and eosin; × 200. *B*, photomicrograph at higher magnification of a portion of the meniscus shown in *A*. There is uniformity of cellular structure, with no evidence of a synovial layer. Hematoxylin and eosin; × 560.

In the embryo of 13 weeks little change as far as differentiation is concerned can be seen. The meniscuses appear to contain collagenous matrix, and there is abundant reticulum. There is no synovial lining over the articular surfaces. The

blood vessels are now seen in the periphery of the meniscuses and in the connective tissue about the cruciate ligaments.

At the age of approximately 13½ weeks, the cartilage of the joint shows further progression toward maturity and the same layer of flattened, elongated cells persists

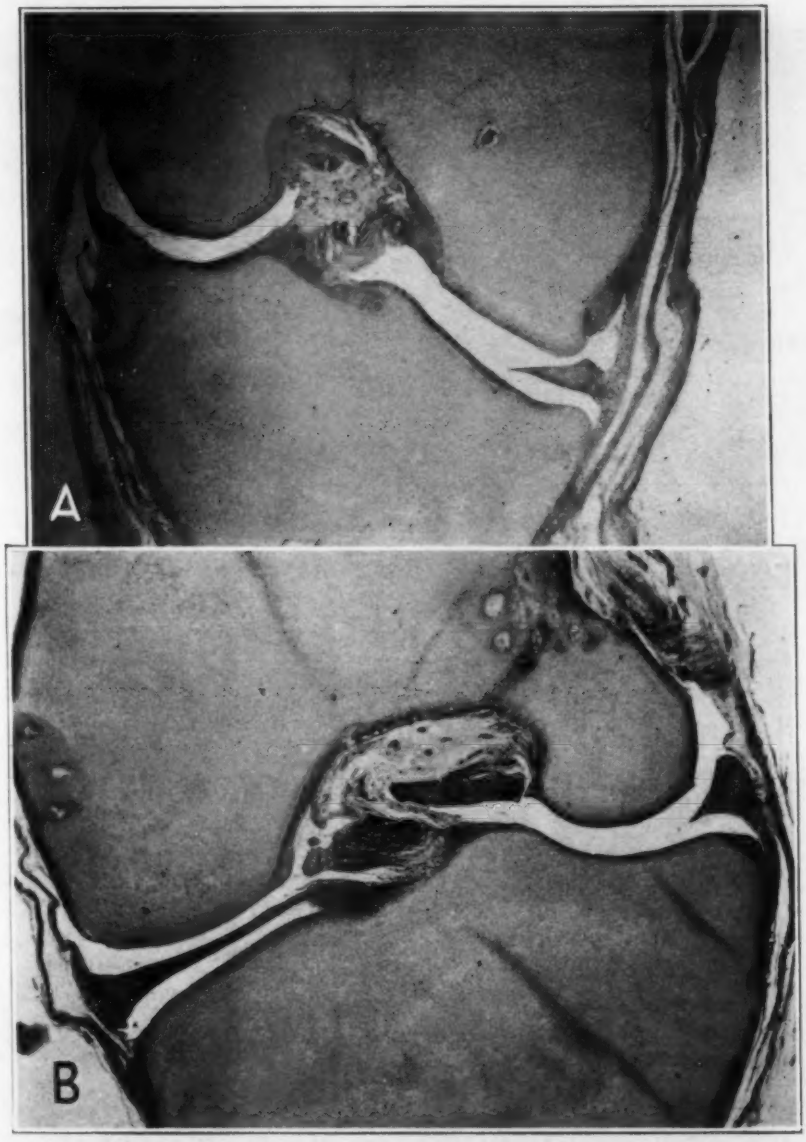

Fig. 5.—*A*, photomicrograph of a coronal section of a knee joint at the fetal age of 12½ weeks, showing well developed meniscuses and the extent of the articular cavity. Hematoxylin and eosin; × 19. *B*, photomicrograph of an oblique section of a knee joint at the fetal age of 13½ weeks, showing the contour of the joint space, the meniscuses and prominent cruciate ligaments (center). Aniline blue; × 20.

over the articular surfaces. There is more collagenous matrix, and the reticulum in the capsule and meniscuses as well as in the cruciate and coronary ligaments is less. There is a hardly perceptible union of coronary ligaments and

meniscuses. The latter are of the same distribution and configuration as the adult disk. The cells forming the meniscuses show an increasing tendency for their fibers to be arranged as straight and slightly wavy collagen bundles. The cruciate ligaments are better separated from the meniscuses at the anterior and posterior ends of the latter. They can now be recognized as separate entities because of

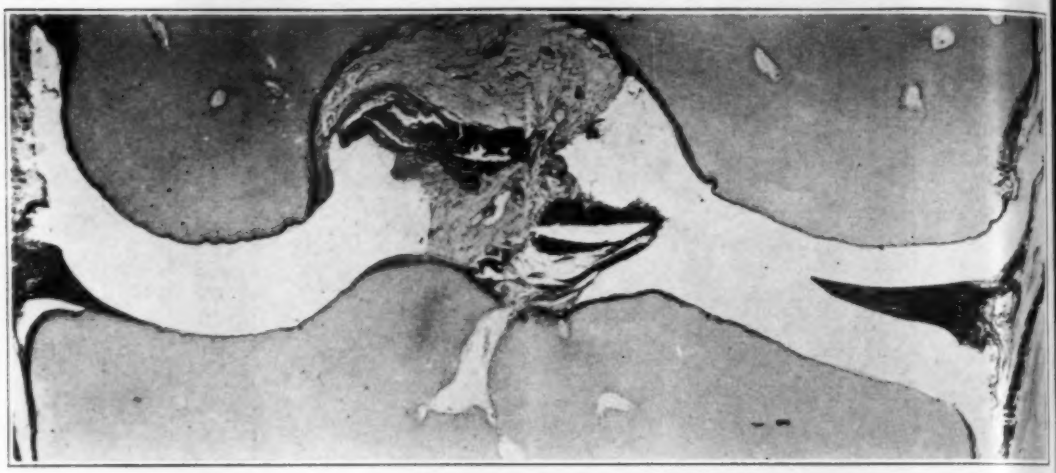

Fig. 6.—Photomicrograph of a coronal section of a knee joint at the fetal age of 15 to 16 weeks, showing the meniscuses and the cruciate ligaments, which, together with the joint space, show little change from the status seen in figure 5 *B* other than increase in size. Hematoxylin and eosin; × 16.5.

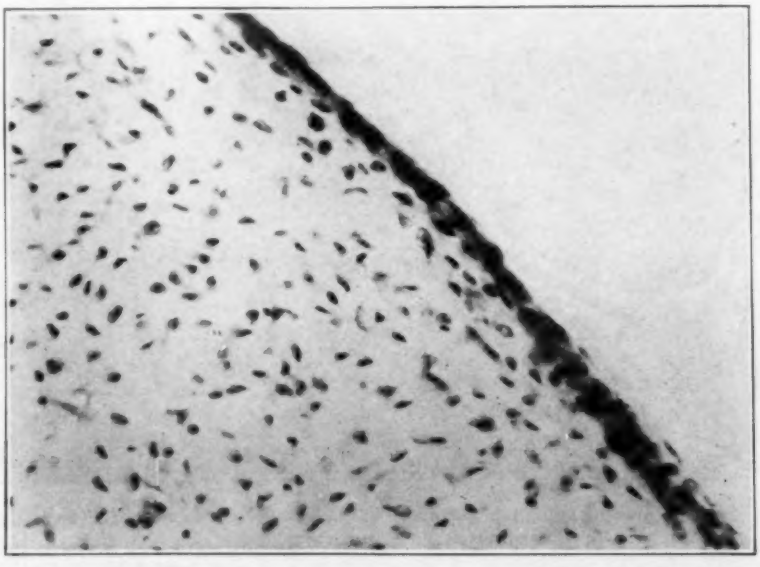

Fig. 7.—Photomicrograph of a portion of a meniscus at the fetal age of 20½ weeks. The cellular detail is well shown (fibroblasts), and the definition of a synovial layer is striking as a special arrangement of the surface fibroblasts. Hematoxylin and eosin; × 350.

the fact that the point of union is marked by less densely compacted cells (fig. 5 *B*). The ligamentum mucosum and the alar ligaments are composed of well developed

fibroblasts with a small amount of collagen. They are moderately vascular, the vessels being chiefly capillaries and small vessels with poorly developed walls. No definite synovial membrane is recognized. The mesenchymal tissue about the cruciate ligaments is smaller in amount, loose and edematous and shows areas of degeneration.

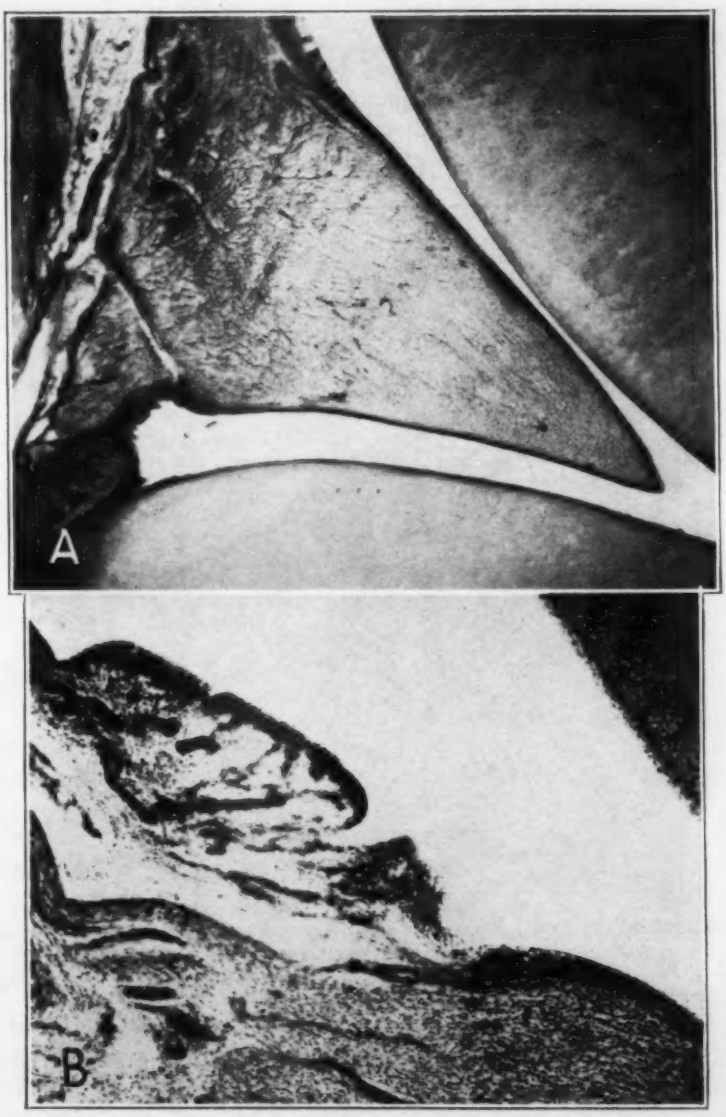

Fig. 8.—*A*, photomicrograph of a sagittal section of a coronary ligament and a meniscus at the postnatal age of 3 weeks. A dense synovial layer is seen covering the entire free surface of the meniscus. Note the small blood vessels in the coronary ligament and in the outer two thirds of the meniscus, with a relatively avascular central region of the latter structure. Hematoxylin and eosin; × 22. *B*, photomicrograph of a sagittal section of a coronary ligament and a meniscus with the adjacent joint surface at the postnatal age of 3 weeks. Note the absence of a synovial covering over the articular cartilage at the right upper corner. Hematoxylin and eosin; × 60.

During the following two to three weeks the changes are chiefly those of increased growth and more complete differentiation of individual cells (fig. 6). The articular surfaces of the bones are covered by a thin layer of flattened cells, and beneath this normal hyaline cartilage is easily recognized. Blood vessels can be seen in the outer portions of the meniscuses. The connective tissue about the cruciate ligaments is more loosely arranged, less in amount and more vascular. The meniscuses are very compact and contain increasing amounts of collagen, but no cartilage matrix.

At the age of 18 weeks growth has become more and more rapid and the process of differentiation more complete. The meniscuses show blood vessels extending well into them, even to their tips, so that they are highly vascular in some places. The cruciate ligaments stand almost alone, and a few vascular

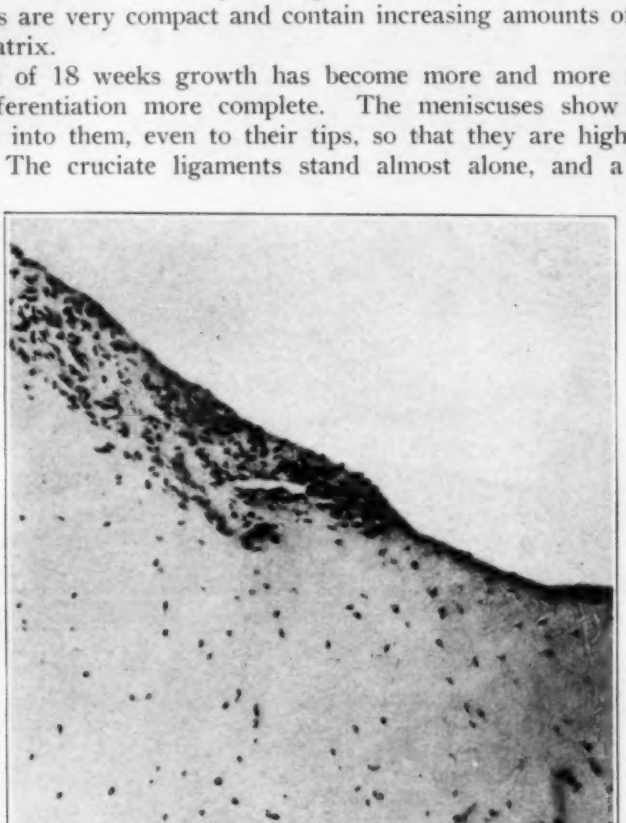

Fig. 9.—Photomicrograph of the free border of a meniscus at the age of 5½ years, showing the presence of a synovial membrane over the vascular external portion on the left and abrupt disappearance of the membrane over the avascular weight-bearing area. Hematoxylin and eosin; × 150.

elements are noted within them. A definite synovial lining is not seen, but in some areas on the surfaces of the meniscuses the cells appear to be undergoing rearrangement. This consists merely of a more dense grouping of the constituent cellular elements involving those closest to the free surfaces for a depth of four or five cells.

During the following week the chief changes in addition to growth are the increase in vascularity of the cruciate and coronary ligaments and the appearance of definite fat cells in the mass of connective tissue inferior to the patella, so that now a definite infrapatellar fat pad becomes a reality. Previously there has been only a mass of loosely arranged fibrous tissue. The synovial membrane is not as yet definite.

When the embryo has reached 20½ weeks, the femoral condyles are quite prominent and the intercondylar notch proportionately deep. Each articulating surface presents, parallel to the surface, a thin layer of elongated cells, between which one finds little matrix. It now resembles very closely that in the adult. Reticulum is no longer present in this region. Along the free borders of each meniscus the cells are somewhat more flattened and form a distinct compact layer. Some of the surface cells project into the cavity. This layer, although composed of the same elements as the bulk of the meniscus, is different in the arrangement of its cells. It is interpreted as being the first definite evidence of the formation of a more specialized layer lining the joint, and may be called the synovial membrane (fig. 7). It is not uniform and in some areas appears to extend over the entire meniscus as far as the latter's attachment to the capsular and coronary ligaments and for a short distance over the joint aspects of these structures. No synovial membrane is seen in other portions of the joint except possibly over portions of the ligamentum mucosum and alar ligaments. The regions immediately beneath the synovial membrane are very vascular.

At 29 to 30 weeks there is little increase in the amount of adipose tissue in the future infrapatellar fat pad. There has been great increase in growth of all the structures with little modification of form. The articular surfaces are more mature and are now composed of hyaline cartilage to their ends, except for a few flattened elongated cells. The synovial membrane appears to line the entire joint space except over the ends of the bones. Synovial villi are beginning to make their appearance.

At birth the changes from the foregoing picture are of growth only. The meniscuses are covered by synovial membrane on all aspects except at the point of attachment to the coronary ligaments and the capsule (fig. 8). They are quite vascular except at their tips.

During the following two to three years the alterations within the knee joints are primarily those of growth with one striking exception, viz., the meniscuses become more and more avascular and the amount of collagen increases rapidly. The final result is that they consist of masses of dense collagenous tissue, the inner two thirds of which is entirely without blood vessels. Equally striking is the fact that the synovial membrane disappears from the free borders in those areas which bear weight (fig. 9). At no time during childhood was any suggestion of cartilage matrix noted in the meniscuses.

COMMENT

In the microscopic development of the human knee joint it is difficult to recognize any but a few definite manifestations of phylogenetic phenomena.[7] However, they can be recognized readily in the infrequent congenital anomalies seen at operations, at postmortem examinations and in dissecting rooms.[11] Discoid and ring-shaped meniscuses are not too infrequently encountered, and their origin is explained by those interested in comparative anatomy.[12] The same applies to various types of division of the articular cavity and types of meniscal attachment.[13]

It is important to appreciate the fact that the meniscuses are well developed long before there is any suggestion of a synovial lining in the joint, especially

11. Chandler, F. A.: Congenital Abnormalities of the External Semilunar Cartilage, S. Clin. North America **17**:331-334 (April) 1937. Ellis, V. H.: Congenital Abnormality of External Semilunar Cartilage, Lancet **1**:1359 (June 25) 1932.

12. Finder, J. G.: Discoid External Semilunar Cartilage, J. Bone & Joint Surg. **16**:804 (Oct.) 1934. Jaffe, H. L.: Comparative Anatomy of Semilunar Cartilages of the Knees: Normal Presence of Bone in Menisci of Some Animals, Arch. Path. **15**:599 (April) 1933.

13. Herzmark, M. H.: Evolution of the Knee Joint, J. Bone & Joint Surg. **20**:1 (Jan.) 1938.

when one attempts to explain the genesis of meniscal cysts on a developmental basis.[14] The fact that the synovial membrane is first seen at approximately the time fetal movements are usually recognized by the mother is certainly interesting. Also it seems that this covering disappears from those portions of the meniscuses that are exposed to weight bearing at the period when the child is beginning to bear weight and use his knee joints really well.[15]

Nothing which could contribute to the information on the origin of synovial fluid was recognized in this study with one exception. It is quite definite that the synovial membrane is entirely derived from connective tissue, by rearrangement of cells rather than by special differentiation.

The meniscuses which are so commonly termed semilunar cartilages are in childhood, at least, composed of collagenous tissue, and one may well feel that the term "meniscuses" is preferable.

The intra-articular structures, which are derived from a common source, appear to arise directly in the same relative position in which they are found in the fully developed joint. Accordingly it is difficult to accept the suggestion that the meniscuses and the cruciate ligaments are secondary invasions into the joints with reflected synovial membrane to cover them. Furthermore, the synovial membrane appears to result only from a rearrangement of fibrous tissue cells on the inner surface of the capsule and over the free borders of the meniscuses; it has the same origin as the structures it covers and does not present an appearance which would suggest an epithelial or an endothelial nature.

Keith's idea that the cruciate ligaments arise from inclusion of a portion of the posterior capsule within the joint does not seem to be borne out by my observations that the curve of the condyles changes little if any after the appearance of the capsule. The cruciate ligaments can be seen to arise directly by condensation and differentiation of the blastemal tissue of the interchondral disk as early as 9 to 10 weeks, at which time the capsule is little in evidence.

The perichondrium is well differentiated before the appearance of the synovial membrane. Although both have a common source in the undifferentiated blastema of the limb bud, it does not seem reasonable to assume that the perichondrium gives rise to the synovial lining of the joint as Keith suggests.

I was able to recognize cruciate ligaments prior to the appearance of the capsule, contrary to the observations of Bardeen, but am in agreement with his statement that the meniscuses and the cruciate ligaments are differentiated directly from the blastema.

SUMMARY

The development of the knee joint is traced by means of serial sections from the third week of fetal life to birth, and the meniscuses are studied to the age of 12 years. Particular emphasis has been placed on the embryologic origin of the intra-articular structures and the chronologic relationship between the meniscuses and the synovial membrane. Topographic rearrangements of the synovial membrane in early childhood are recorded.

A review of some of the literature on the knee joint in the field of comparative anatomy, as well as a review of the more significant available literature in that of embryology, has been included.

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14. King, E. S. J.: The Formation of Ganglia and Cysts of the Menisci of the Knee: Observations on the Golgi Apparatus, Surg., Gynec. & Obst. **70**:150 (Feb.) 1940.

15. MacConaill, M. A.: The Function of Intra-Articular Cartilages, J. Anat. **66**:210 (Jan.) 1932.

CONCLUSIONS

1. The articular cavity of the knee joint develops by disappearance of cells from the substance of the dense blastemal interchondral disk between the tibia and the femur, with coalescence of several primary spaces.

2. The meniscuses and the intra-articular ligaments, as well as the capsule, are differentiated directly from the blastema which remains after the disappearance of cells resulting in the formation of the joint space.

3. The synovial membrane makes its appearance by rearrangement of cells over the free borders of the meniscuses and the inner surface of the capsule after these structures have been well differentiated.

4. At no time does the synovial membrane cover the articular surfaces of the bones.

5. The synovial membrane does not consist of endothelial cells.

6. The meniscuses are fully developed several weeks before the appearance of the synovial membrane.

7. Limb buds are seen during the third week of fetal life.

8. The time of appearance of various structures of the knee joint is as follows: joint space, eighth week, complete at the twelfth week; meniscuses, ninth to tenth week; capsule, ninth to tenth week; cruciate ligaments, ninth to tenth week; cartilaginous patella, tenth week; coronary ligaments, twelfth to thirteenth week; synovial membrane, eighteenth to twentieth week; infrapatellar fat pad, nineteenth week; synovial villi, twenty-ninth to thirtieth week.

9. After birth the inner two thirds of the meniscuses becomes increasingly avascular, and at about 2½ years of age the synovial membrane has completely disappeared from these weight-bearing areas of the meniscuses.

10. During childhood the meniscuses contain no cartilage matrix.

11. Few definite evidences of phylogenetic phenomena are noted in serial sections of the knee joints.

12. The term "meniscuses" is to be preferred to "semilunar cartilages" when referring to the intra-articular disks of the knee joint.

ADDENDA

The data and criteria for determination of fetal age were based on foot length and crown-rump length as well as crown-heel length of the fetus.

Guidance, criticism and advice in this work were given by Dr. Frank R. Ober, John Ball and Buckminster Brown professor of orthopedic surgery at Harvard Medical School; Dr. William T. Green, assistant professor of orthopedic surgery; Dr. Sidney Farber, assistant professor of pathology, and Dr. Granville A. Bennett, assistant professor of pathology. Permission to use the embryologic collection of Harvard Medical School was given by Dr. J. Lewis Bremer, Hersey professor of anatomy. Miss Mary McNally prepared serial sections of specimens; Mr. Charles Miller made the photomicrographs, and Miss Helen Purtle, of the department of pathology of the Children's Hospital, aided in the revision of the manuscript.

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FRACTURE OF THE NECK OF THE ASTRAGALUS

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In the past quarter century, spanning the years 1919 to 1943, fracture of the neck of the astragalus has received but scant attention. The few reported end results have been discouraging. A search of the literature over this period reveals not more than seventy-five papers dealing with this injury. These contributions, for the most part, are in the foreign literature.

Most of these reports record isolated instances of fracture of the astragalar neck because of its rarity. The commonly employed therapy has been total or partial astragalectomy. This form of treatment in the case of an adult is an admission of inadequacy surpassed only by amputation.

In the English literature of these same years there have been twenty-one treatises on fracture involving the neck of the astragalus. Seventeen reports have been from the United States; four have been from Great Britain. Again, the majority of these papers have value only as tabulations of individual cases, and astragalectomy, total or partial, has been the usual treatment. Only nine works in the English language deserve special consideration.

Sneed [1] reported the case of a patient with total dislocation of the astragalus who refused to submit to astragalectomy. Reduction was accomplished only after complete excision and replacement of the astragalus. The articular cartilage was not eraded from either the tibial or the calcaneal surface of the bone. It is stated that four years after this injury the patient had a satisfactory functional result and a painless foot, although dorsiflexion and plantar flexion of the ankle joint were moderately limited and motion in the subastragalar joint was markedly restricted.

Sneed also carried out a series of injections on amputated legs and from these experiments inferred that the astragalus is supplied with blood not by one main nutrient artery but by several small arteries. He concluded that even though the vascular supply of the astragalus is interrupted, replacement of the bone offers hope of good function. It is interesting that his one photograph demonstrating blood vessels in the astragalus by injection shows them to be present only in the neck and to originate on the superior surface.

Graham and Faulkner [2] reviewed the case records of 10 patients who were seen late and who were treated by total astragalectomy. Although they granted the severe disability resulting from astragalectomy, they held this procedure to be the one of choice for patients coming under observation late or for patients coming under observation early with severe comminution of the astragalar body. For patients seen reasonably early without severe comminution of the astragalus, they advocated open replacement as offering less disablement in the future.

Phemister [3] at a meeting of the American Orthopedic Association in 1932 presented an experimental study, "Transplantation of the Astragalus," which has

1. Sneed, W. L.: Astragalus: Case of Dislocation, Excision, and Replacement; an Attempt to Demonstrate Circulation in This Bone, J. Bone & Joint Surg. **7**:384-399 (April) 1925.

2. Graham, W. T., and Faulkner, D. M.: Fractures of the Astragalus: Ten Cases Treated by Astragalectomy, Ann. Surg. **89**:435-438 (March) 1929.

3. Phemister, D. P.: Transplantation of the Astragalus, to be published.

a direct bearing on the problem of treatment of fracture of the neck of the astragalus. He showed in animals that the enucleated astragalus when replaced constantly underwent aseptic necrosis. However, when the articular cartilage was removed from the bone, revascularization was tremendously accelerated. He concluded that the articular cartilage acted as a barrier to the ingrowth of new blood vessels.

In 1940 Phemister [4] reported 2 cases of aseptic necrosis of the astragalus after fracture, in 1 of which there was no displacement of the fragments, and called attention to the effect of degeneration of the underlying bone on the articular cartilage of the astragalus. In this article he presented excellent pathologic studies.

Gibson and Inkster [5] contributed an excellent consideration of the mechanogenesis of this fracture. They attributed some vascular supply to small arteries entering the astragalus through the attachments of the deltoid ligaments. Certain criteria for treatment were outlined. In their opinion a complete posterior dislocation of the body through a buttonhole between the flexor tendons completely severed the body of the astragalus from its vascular connections. They felt that in this circumstance simple replacement leads to necrosis of the body and advised panastragalar arthrodesis. A perusal of the roentgenograms reproduced in their paper reveals aseptic necrosis of the astragalus even in their patients who did not have such severe dislocation. They condemned partial astragalectomy as producing a heel walker.

Conwell and Alldredge [6] reported on a patient who suffered a compound fracture–dislocation of the astragalus. The fragments were replaced without excising the cartilage. The result after eleven months is shown. Although severe deformation and considerable sclerosis of the astragalus resulted, the authors maintained that this procedure is superior to astragalectomy and subscribed to the statement of Sneed that revascularization of the bone may occur.

Miller and Baker [7] in reporting a series of cases of fracture of the astragalus advised against astragalectomy and recommended that triple arthrodesis be performed early if accurate reduction is impossible. Nineteen of his patients were followed long enough to be considered as showing end results. Of these 19 patients, 15, or 79 per cent, had pain, deformity or limp, or all three, and 1 had an elective amputation. They quoted Sneed's work of 1925 in stating that the astragalus has no main nutrient artery.

Boyd and Knight [8] called attention to the poor results obtained in treating fractures of this type and advised open reduction if there is any displacement and stated that severe displacement may require subastragalar fusion. They condemned astragalectomy.

Schrock, Johnson and Waters Jr.[9] called attention to the constancy of sclerosis of the body of the astragalus and of traumatic arthritis of the tibiocalcaneal joint. Later, however, they attributed this to crushing trauma of the dome of the

4. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation, Arch. Surg. **41**:436-472 (Aug.) 1940.

5. Gibson, A., and Inkster, R. G.: Fractures of the Neck of the Astragalus, Canad. M. A. J. **31**:357-362 (Oct.) 1934.

6. Conwell, H. E., and Alldredge, R. H.: Complete Compound Comminuted Fracture-Dislocation of Astragalus, Surgery **1**:222-227 (Feb.) 1937.

7. Miller, O. L., and Baker, L. D.: Fractures of the Astragalus, South. M. J. **32**:125-136 (Feb.) 1939.

8. Boyd, H. D., and Knight, R. F.: Fractures of the Astragalus, South. M. J. **35**:160-167 (Feb.) 1942.

9. Schrock, R. D.; Johnson, H. F., and Waters, C. H., Jr.: Fracture and Fracture-Dislocations of the Astragalus (Talus), J. Bone & Joint Surg. **24**:560-569 (July) 1942.

astragalus with infractions of the articular cartilage rather than to disturbance of circulation. They advised against astragalectomy and proposed a tibial-astragalar-calcaneal arthrodesis, using, if necessary, fragments of a comminuted astragalus. They reported 6 cases of fracture of the neck of the astragalus.

Modern textbooks of orthopedic surgery and of the treatment of fractures also offer a variety of opinions concerning the treatment of fracture of the type under discussion.

Böhler [10] presented fracture of the neck of the astragalus as a simple mechanical problem, stating that as a rule it is reduced by traction but that occasionally it requires open reduction, which results in good function after eight weeks' immobilization. He advised against astragalectomy but gave no consideration to any vascular disturbance and disregarded the physiology of repair.

Speed [11] recommended simple immobilization in cases in which there is no displacement or in which reduction can be effected. For cases in which reduction is impossible he advised removal of the displaced fragment (partial astragalectomy). He stated that most of the fractures of this type eventually come to astragalectomy and stressed the frequency of infection after open reduction.

Magnuson [12] stated that in cases of fracture of the neck of the astragalus with displacement there is always some permanent disability. He said, "Because of complete loss of blood supply the fracture does not heal kindly and consequently the fragment may form a foreign body in the joint." For fracture with displacement he advocated arthrodesis of the ankle joint.

Destot [13] stressed the mechanical difficulties of both accurate open and closed reduction and emphasized the importance of accurate replacement. He advised against partial astragalectomy and held that total astragalectomy should be reserved for those cases in which the body of the astragalus is damaged or those in which open reduction is impossible. Closed reduction is only occasionally successful, he stated. No illustrations of the blood supply are offered, but Ollier is quoted as saying that the astragalus is a poorly nourished bone and that the lack of nourishment accounts for the frequent localization of tuberculosis in this region.

Wilson [14] called attention to the fact that the nutrition of the astragalar body is cut off if there is displacement. On the basis of results in 5 patients, 4 of whom were treated by total astragalectomy and 1 of whom was treated by replacement, he had become a protagonist of astragalectomy and advised against replacement. Fifty per cent of the patients subjected to astragalectomy were reported as having a good result, and in the 1 patient in whom replacement was carried out the end result was a failure.

Scudder [15] in a brief paragraph dismissed fracture of the astragalus with the statement that after two to three months of immobilization of the foot the patient may walk without support but may have some pain for four to six weeks after the injury. The illustrations in the eleventh edition of his work are taken from Cabot and Binney and clearly show circulatory changes in the body of the astragalus.

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10. Böhler, L.: Treatment of Fractures, ed. 4, translated from the fourth German edition by E. W. H. Groves, Baltimore, William Wood & Company, 1941.

11. Speed, K.: Fractures and Dislocations, Philadelphia, Lea & Febiger, 1942.

12. Magnuson, P. B.: Fractures, ed. 3, Philadelphia, J. B. Lippincott Company, 1939.

13. Destot, E.: Traumatismes du pied et rayone X, ed. 2, Paris, Masson & Cie, 1937.

14. Wilson, P. D.: Management of Fractures and Dislocations, Philadelphia, J. P. Lippincott Company, 1938.

15. Scudder, C. L.: The Treatment of Fractures, ed. 11, Philadelphia, W. B. Saunders Company, 1938.

Key and Conwell [16] held that astragalectomy is indicated only in the presence of sepsis. For severe displacement they advised panastragalar arthrodesis to prevent aseptic necrosis of the proximal fragment. Their illustrations clearly demonstrate the lack of demineralization posterior to the fracture line.

Watson-Jones [17] offered sketches of the blood supply of the astragalus showing vessels entering all ligamentous attachments in great adequacy and called attention to the seriousness of avascular necrosis as a disabling factor. He stated, however, that the blood supply of the astragalus is sufficient to prevent avascular necrosis

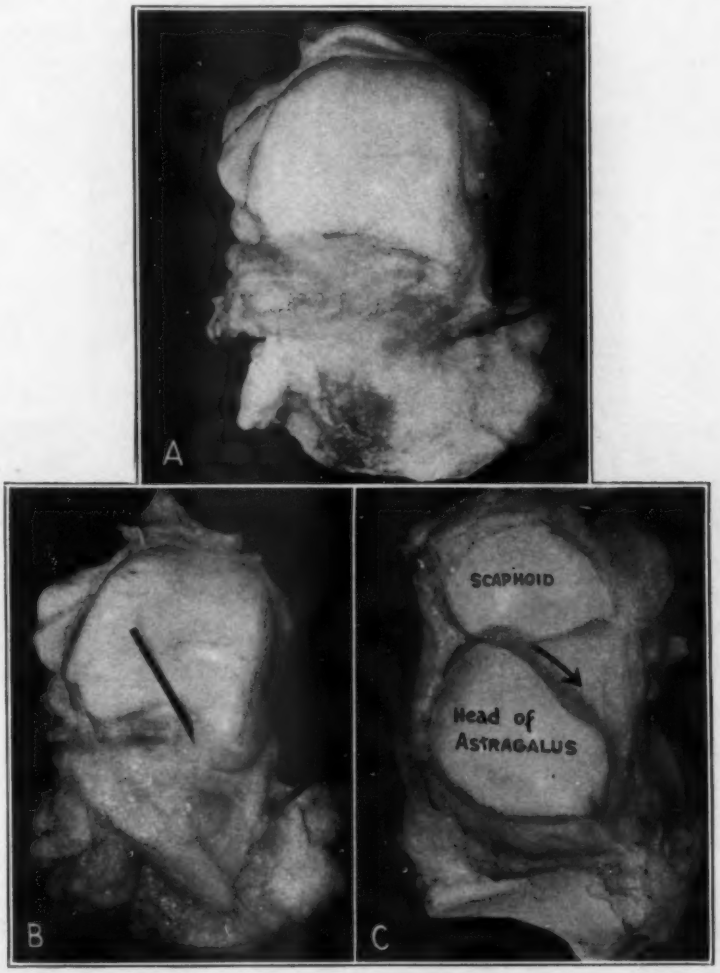

Fig. 1.—*A*, astragalus with the superior astragaloscaphoid ligament attached to its neck and a pointer in its artery. *B*, astragalus with the superior astragaloscaphoid ligament reflected forward and arrows pointing to vessels going into the portion of the neck not covered by cartilage between the body and the head. *C*, astragalus, scaphoid and attached superior astragaloscaphoid ligament. The scaphoid is lifted up, with the head of the astragalus facing. Vessels in the superior astragaloscaphoid ligament are going into the neck near the body.

16. Key, J. A., and Conwell, H. E.: Fractures, Dislocations, and Sprains, ed. 3, St. Louis, C. V. Mosby Company, 1942.

17. Watson-Jones, R.: Fractures and Other Bone and Joint Injuries, Baltimore, Williams & Wilkins Company, 1940.

unless backward dislocation of the body occurs. This is not borne out by clinical experience, and it is believed he attributed too ample a circulation to the astragalus.

The purpose of the present paper is to present (1) the intrinsic circulation of the astragalus as revealed by injection, (2) the end results in 17 patients who suffered fracture of the neck of the astragalus and (3) some principles of treatment based on a study of the circulation of blood in the bone and of the clinical course of fracture of the astragalar neck.

INTRINSIC CIRCULATION OF THE ASTRAGALUS AS REVEALED BY INJECTION

To demonstrate the arterial ramifications in the astragalus, freshly amputated feet were used. The vascular system of each amputated specimen was first washed

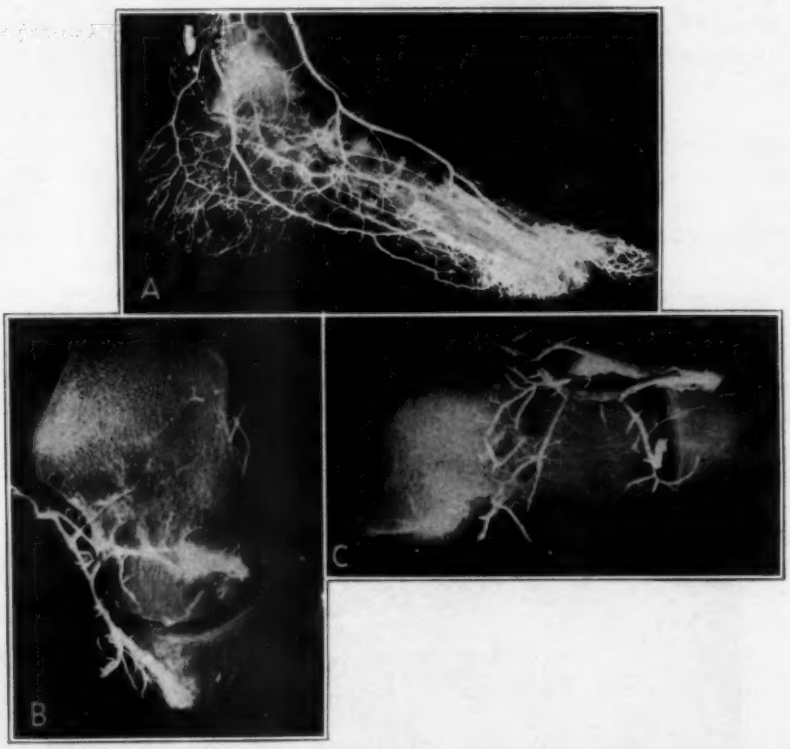

Fig. 2.—Roentgenograms: *A*, foot with the soft tissues intact, after metallic mercury had been injected into the vascular system. A branch of the anterior tibial artery goes to the astragalar neck. The posterior tibial artery passes by the astragalus. The vascular network even in the soft tissues in the region of the astragalus is sparse compared with the remaining vascular bed. *B*, anteroposterior view of the astragalus and the scaphoid with all ligaments attached. The vessels in the superior astragaloscaphoid ligament with their ramifications to the neck stand out plainly. *C*, lateral view of the same specimen. Note the lack of vascularity posterior to the neck.

by perfusing with tap water for six to eight hours. The arterial trunks, the anterior tibial artery and the posterior tibial artery were then injected with a radiopaque medium under pressure. In some instances metallic mercury was used. In others a suspension of yellow oxide of lead (lead monoxide N. F.) in olive oil was the substance injected. The venous side was ligated before the injections were made.

After the injections had been made, roentgenograms were obtained of (1) the entire foot, (2) the astragalus and the scaphoid with all attached ligaments but without other soft tissue and (3) the isolated astragalus, scraped clean of all ligaments.

Seven feet were used. They were all free of arterial disease and had been amputated for morbid conditions higher in the extremity or distal to the ankle, such as osteogenic sarcoma of the femur, intractable sepsis at the knee and complete traumatic amputation. In 4 of the specimens after the astragalus had been cleanly denuded of all ligaments the isolated bone failed to show evidence of the injected

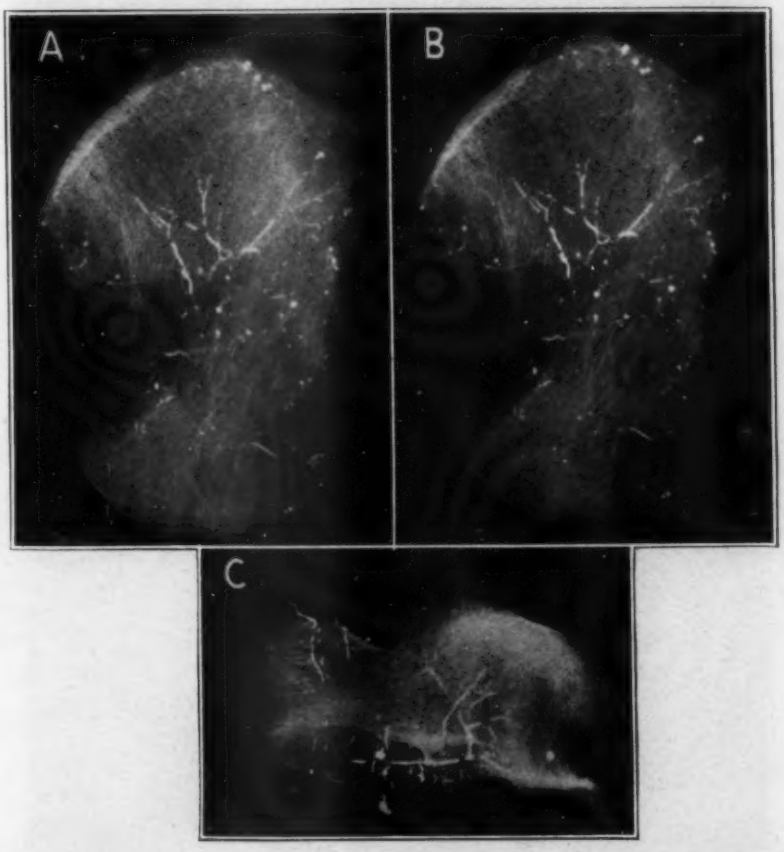

Fig. 3.—Roentgenograms: *A*, anteroposterior view of the astragalus scraped clean of all ligaments. The injected material in the bone is largely in the neck region. The body shows no evidence of blood vessels in the interior. *B*, posterior-anterior view of the same specimen. *C*, lateral view of the same specimen. Note the absence of injected material in the posterior third and the preponderance of vessels in the neck.

material within its substance despite the fact that the arterial tree of the overlying soft tissues was completely outlined. This suggests that the arteries entering the astragalus are of small caliber.

The injected arteries suggest that the entire vascular supply of the astragalus is derived from branches of the anterior tibial artery. There is evidence also that the artery, which eventually breaks up into several nutrient arteries, is carried in the dense astragaloscaphoid ligament (B N A, ligamentum talonaviculare dorsale)

which extends as a broad band from the dorsal surface of the neck of the astragalus to the dorsal periphery of the scaphoid. In this ligament the artery divides into several (two to four) smaller arteries which perforate the superomedial aspect of the neck of the astragalus, where foramens are clearly present.

No evidence of arteries perforating from either the posterior or the anterior calcaneoastragalar ligament or from the internal calcaneoastragalar ligaments in the subastragalar joint was apparent. In no instance was it possible to demonstrate arteries throughout the body of the astragalus.

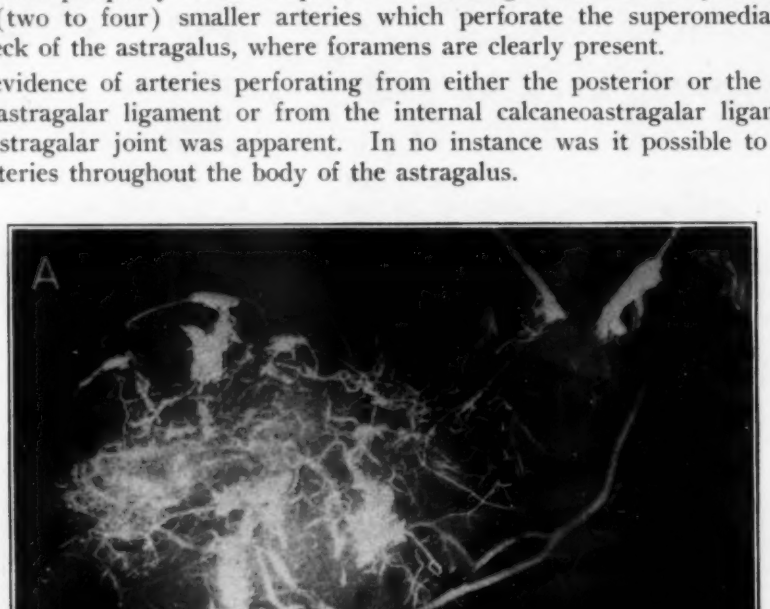

Fig. 4.—Roentgenograms: *A*, foot of a 4 month old infant in which the vessels have been injected with lead monoxide in olive oil. The posterior tibial artery gives off no branches to the astragalus. All vessels going to this area come from the dorsum of the foot. The foot was amputated for fibrosarcoma. *B*, astragalus, scaphoid and all ligaments. The scaphoid does not show because of the lack of an ossification center at this age, and only the nucleus of the astragalus is clear. Note the vessels in the superior astragaloscaphoid ligament.

SURVEY OF PATIENTS AND THEIR TREATMENT

Seventeen patients who suffered a fracture of the neck of the astragalus were examined clinically and studied by roentgenograms to determine the end results of various treatments and the relation of the original displacement of the fractured

fragments to the outcome. The shortest period that elapsed after the injury in any case was one and one-half years and the longest was eleven years.

Of these 17 patients, all but 3 (82 per cent) were under 40 years of age, in the active, vigorous period of life. Three were children. In 5 patients the fracture was subjected to open reduction. In all of these the body of the astragalus was completely removed and replaced in its entirety, with all articular cartilage intact. Six patients were treated by closed manipulation and immobilization of the extremity. Simple immobilization of the foot and leg in plaster was all that was necessary for 5 patients, due to the fact that there was no displacement of the fragments. Astragalectomy was done on 1 patient.

RESULTS

Only 4 of the 17 patients (23 per cent) were free of pain, had no restriction of motion in the ankle or the subastragalar joint and could carry on normal activity. These 4 were all patients who had sustained incomplete fracture of the

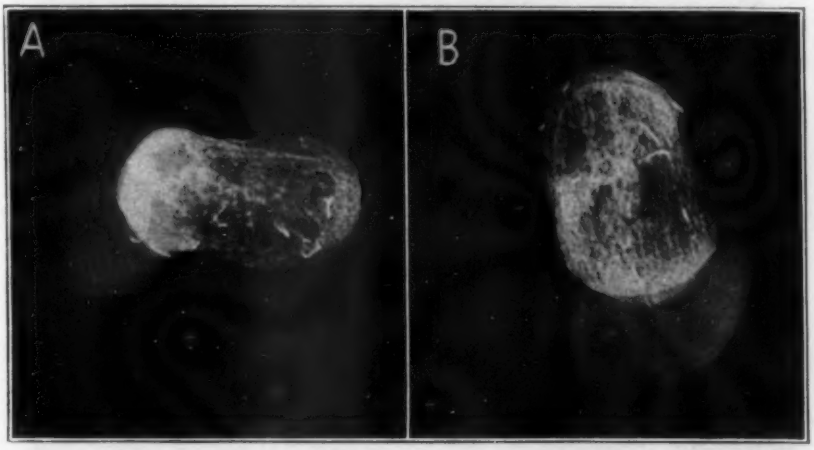

Fig. 5.—Roentgenograms: *A*, lateral view of an astragalus scraped clean of all ligaments. The ossification center stands out clearly; the cartilaginous portion is hazy. Injected material is seen in and about the periphery of the ossification center. None is evident in the cartilaginous portion. The majority of the vessels are in the neck region. *B*, anteroposterior view of the same specimen showing injected material in the bony nucleus, which is largely in the neck.

neck of the astragalus with no displacement. Their roentgenograms showed only a serrated line across the neck. None of these patients exhibited evidence of aseptic necrosis of the body of the astragalus at any time during the course of healing. All that was necessary in their treatment was immobilization. Case 14 illustrates their type of case.

Case 14. *(Incomplete Fracture of Neck of Astragalus).*—A. J., a nurse 20 years of age, was thrown from a horse, catching her foot in a stirrup, and was dragged 30 feet (9 meters) on Oct. 3, 1931. Roentgen examination revealed incomplete fracture of the neck of the left astragalus. The left leg and foot were immobilized in a cast for ten weeks, and the patient used crutches for another six weeks. She returned to work in February 1932 and had no trouble thereafter. In February 1939, eight years after injury, motion in the ankle joint and subastragalar joint was normal. Roentgenograms showed a normal astragalus and normal ankle and subastragalar joints. She stated that she suffered no pain, did her regular work, played tennis and danced.

One patient who suffered incomplete fracture of the neck of the astragalus had a painful foot, with moderate restriction of motion in the ankle and subastragalar joints, one and one-half years after injury. Roentgenograms showed evidence of aseptic necrosis of the body of the astragalus and thinning of the cartilage space of both the ankle and the subastragalar joint despite the fact that the original injury produced no separation of the fragments (case 13).

CASE 13 *(Incomplete Fracture of Neck of Astragalus, with Development of Aseptic Necrosis).*—F. L., an accountant 57 years of age, slipped and fell backward as he stepped up a high curbing on Feb. 9, 1938. Roentgenograms revealed incomplete fracture of the neck of the left astragalus without displacement. The foot and leg were immobilized in a cast for twelve weeks, and weight bearing was prohibited for seven weeks. In January 1940, two years after the injury, dorsiflexion of the ankle was restricted to 90/95 degrees and plantar flexion to 115/120 degrees. In the subastragalar joint inversion was restricted to 10/25 degrees and eversion to 5/10 degrees. Roentgenograms at this time showed aseptic necrosis of the body of the left astragalus and thinning of the cartilage space of both the ankle and the subastragalar joint. The patient complained of pain in the left foot after walking six blocks.

Fig. 6 (case 14).—Roentgenograms: *A*, incomplete fracture of the neck of the astragalus without displacement Oct. 3, 1931. *B*, foot in a cast Oct. 6, 1931. *C* and *D*, lateral views of the left (injured) and the right (uninjured) foot eight years after fracture (Jan. 16, 1939). There is no deformation or sclerosis of the astragalus.

Six patients sustained fracture of the neck of the astragalus with only slight or moderate dorsal displacement of the neck fragment on the body. Closed reduction by manipulation followed by immobilization in plaster seemed adequate. All of these patients, despite the accuracy of the reduction obtained, exhibited aseptic necrosis in the proximal or body fragment during the course of healing. All in the end had painful foot and ankle and showed marked loss of motion in the ankle joint and the subastragalar joint. Roentgen studies of these patients revealed sclerosis of the body of the astragalus and thinning of the cartilage space of both the ankle and the subastragalar joint. One patient, a child, had severe deformation of the dome of the astragalus after this bone had gone through the complete cycle of avascular necrosis and revascularization (case 7).

CASE 7 (*Fracture of Neck of Astragalus Treated by Closed Reduction and Immobilization*).—D. C., a child 6 years of age, jumped from the roof of a garage, alighting with the left foot turned in, July 6, 1936. On July 7, with the patient under anesthesia induced with ether, closed reduction was accomplished. The foot and leg were immobilized in a plaster cast for five months. Weight bearing was prohibited for fourteen months. Roentgenograms taken November 15, five months after the injury, showed aseptic necrosis of the body of the astragalus. On Jan. 6, 1939, two and one-half years after the injury, dorsiflexion of the left ankle was restricted to 70/90 degrees; plantar flexion, to 110/135 degrees. In the subastragalar joint inversion was restricted to 5/35 degrees and eversion to 0/15 degrees. Roentgenograms made in January 1939 showed complete revascularization of the astragalus, marked deformation of the astragalar body and marked thinning of the cartilage space of both the ankle and the subastragalar joint. The child had a marked limp and complained of severe pain.

It has been stated that accurate reduction insures good recovery. In 9 of the 12 patients in this group who exhibited aseptic necrosis of the astragalar body

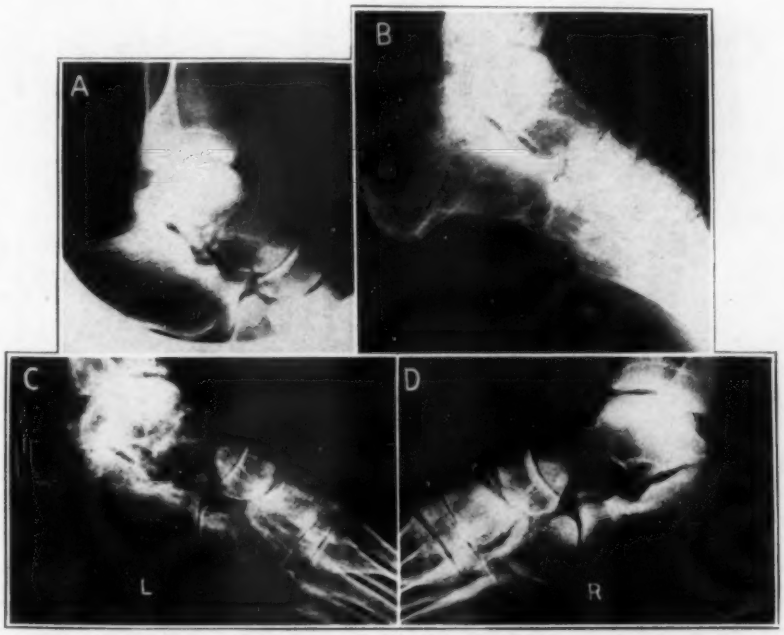

Fig. 7 (case 13).—Roentgenograms: *A*, incomplete fracture of the neck of the astragalus without displacement Feb. 9, 1938. *B*, fracture line partially obliterated four months after injury (June 25, 1938). The body of the astragalus is dense; the remaining tarsal bones are demineralized. *C*, lateral views of the left (injured) and the right (uninjured) foot one year after injury (Jan. 21, 1940). The fracture line is sclerotic. There is some evidence of revascularization in the body adjacent to the fracture line. The ankle joint space and the subastragalar joint space are not severely altered.

fragment perfect reduction was obtained and maintained. In 2 the position of the fragments was good, and in 1 patient the position was poor. This seems to prove that the accuracy of the reduction has little or no influence in preventing aseptic necrosis of the body. Of course, for a good functional result accurate reduction is a requisite of any intra-articular fracture.

Five patients required open reduction. All these patients had displacement of the body of the astragalus through the posterior part of the capsule. This made necessary complete removal of the posterior or body fragment. In all 5 patients

Data on Patients with Fracture of the Neck of the Astragalus

Patient	Age, Yr.	Degree of Separation of Fragments	Treatment	Accuracy of Reduction	Period of Observation	End Result: Motion in Ankle Joint	End Result: Motion in Subastragalar Joint	End Result: Roentgen Findings	End Result: Pain
1 E. J.	17	Complete posterior displacement of body of astragalus	Open reduction; complete removal and replacement of body	Excellent	1 yr. 6 mo.	Dorsiflexion and plantar flexion restricted 10°	Inversion restricted 10°; eversion, 5°	Union; dense sclerosis of body of astragalus, thinning of ankle and subastragalar joint spaces	++
2 D. deS.	30	Complete posterior displacement of body	Open reduction; complete removal and replacement of body	Excellent	11 yr.	Dorsiflexion restricted 15°; plantar flexion, 30°	Inversion and eversion obliterated	Union; dense sclerosis of body of astragalus, marked thinning of ankle and subastragalar joint spaces, osteophytes on margin of ankle joint	+++
3 A. C.	12	Partial posterior displacement of body	Open reduction; complete removal and replacement of body	Good	2 yr.	Dorsiflexion and plantar flexion restricted 15°	Inversion restricted 30°; eversion obliterated	Nonunion; dense sclerosis of body of astragalus, marked thinning of ankle and subastragalar joint spaces	+++
4 C. K.	22	Complete posterior displacement of body	Open reduction; complete removal and replacement of body	Excellent	4 yr.	Dorsiflexion and plantar flexion obliterated	Inversion and eversion obliterated	Union; dense sclerosis of body of astragalus, thinning of ankle and subastragalar joint spaces, osteophytes on margin of ankle joint	+++
5 P. S.	50	Complete posterior dislocation of body	Open reduction; complete removal and replacement of body	Good	3 yr.	Dorsiflexion and plantar flexion restricted 10°	Inversion and eversion obliterated	Union; dense sclerosis of body of astragalus, marked thinning of subastragalar joint spaces	+++
6 B. H.	24	Complete posterior dislocation of body	Total astragalectomy	Position of foot good	2 yr.	Dorsiflexion restricted 25°; plantar flexion, 10°	.....	Good posterior displacement of foot on ankle mortise	+++
7 D. C.	6	Slight displacement of neck on body	Closed reduction	Excellent	2 yr. 6 mo.	Dorsiflexion restricted 20°; plantar flexion, 25°	Inversion restricted 30°; eversion obliterated	Union; complete cycle of aseptic necrosis and revascularization terminating in marked deformity of astragalus and marked thinning of ankle and subastragalar joint spaces	+++
8 W. C.	37	Slight displacement of neck on body; no dislocation of body	Closed reduction	Excellent	2 yr. 5 mo.	Dorsiflexion restricted 10°; plantar flexion, 5°	Inversion restricted 20°; eversion obliterated	Union; dense sclerosis of body of astragalus, moderate thinning of ankle joint space; marked thinning of subastragalar joint space, osteophytes on margin of ankle joint	+++
9 W. McA.	34	Moderate displacement of neck on body; no posterior dislocation	Closed reduction	Good	3 yr.	Dorsiflexion restricted 15°; plantar flexion, 5°	Inversion restricted 20°; eversion obliterated	Union; dense sclerosis of body of astragalus, marked thinning of ankle and subastragalar joint spaces	+

9 W. McA.	34	Moderate displacement of neck on body; no posterior dislocation of body	Closed reduction	Good	3 yr.	Dorsiflexion restricted 15°; plantar flexion, 5°	Inversion restricted 20°; eversion obliterated	Union; dense sclerosis of body of astragalus, marked thinning of ankle and subastragalar joint spaces	+
10 V. H.	26	Slight displacement of neck on body; no posterior dislocation of body	Closed reduction	Excellent	2 yr.	Dorsiflexion restricted 5°; plantar flexion, 10°	Inversion and eversion restricted 10°	Union; dense sclerosis of body of astragalus, marked thinning of subastragalar join space, slight thinning of ankle space	++
11 W. B.	36	Moderate displacement of neck on body; no dislocation of body	Compound wound debrided and closed; manipulative reduction; body not removed	Poor	1 yr. 6 mo.	Dorsiflexion and plantar flexion obliterated; 15° equinus deformity	Inversion restricted 20°; eversion obliterated	Malunion; dense sclerosis of body; marked thinning of ankle and subastragalar joint spaces, marked deformity of astragalus due to poor reduction	+++
12 A. D.	52	Moderate displacement of neck on body; no dislocation of body	Closed reduction	Excellent	1 yr. 6 mo.	Dorsiflexion restricted 5°; plantar flexion, 20°	Inversion and eversion obliterated	Union; dense sclerosis of body of astragalus; marked thinning of ankle and subastragalar joint spaces, slight varus of neck of astragalus	+++
13 F. L.	57	No displacement of neck on body; incomplete fracture	Immobilization in plaster; no reduction necessary	Excellent	2 yr.	Dorsiflexion restricted 5°; plantar flexion, 5°	Inversion restricted 15°; eversion, 5°	Union; dense sclerosis of body of astragalus; marked thinning of ankle and subastragalar joint space	+++
14 A. J.	20	No displacement; incomplete fracture	Immobilization in plaster; no reduction necessary	Excellent	8 yr.	Dorsiflexion and plantar flexion normal	Inversion and eversion normal	Union; no sclerosis of body of astragalus; no thinning of ankle or subastragalar joint spaces	0
15 E. Y.	24	No displacement; incomplete fracture	Immobilization in plaster; no reduction necessary	Excellent	2 yr.	Dorsiflexion and plantar flexion normal	Inversion and eversion normal	Union; no sclerosis of body of astragalus, no thinning of ankle or subastragalar joint spaces	0
16 P. B.	18	No displacement; incomplete fracture	Immobilization in plaster; no reduction necessary	Excellent	1 yr. 6 mo.	Dorsiflexion and plantar flexion normal	Inversion and eversion restricted 5°	Union; no sclerosis of body of astragalus, no thinning of ankle or subastragalar joint spaces	0
17 K. F.	8	No displacement; incomplete fracture	Immobilization in plaster; no reduction necessary	Excellent	2 yr.	Dorsiflexion and plantar flexion normal	Inversion and eversion normal	Union; no sclerosis of body of astragalus, no thinning of ankle or subastragalar joint spaces	0

the body was replaced with its cartilaginous surfaces intact. This group of patients presented the worst end results. All complained of severe pain and had marked restriction of motion in the ankle and the subastragalar joint. The roentgenograms

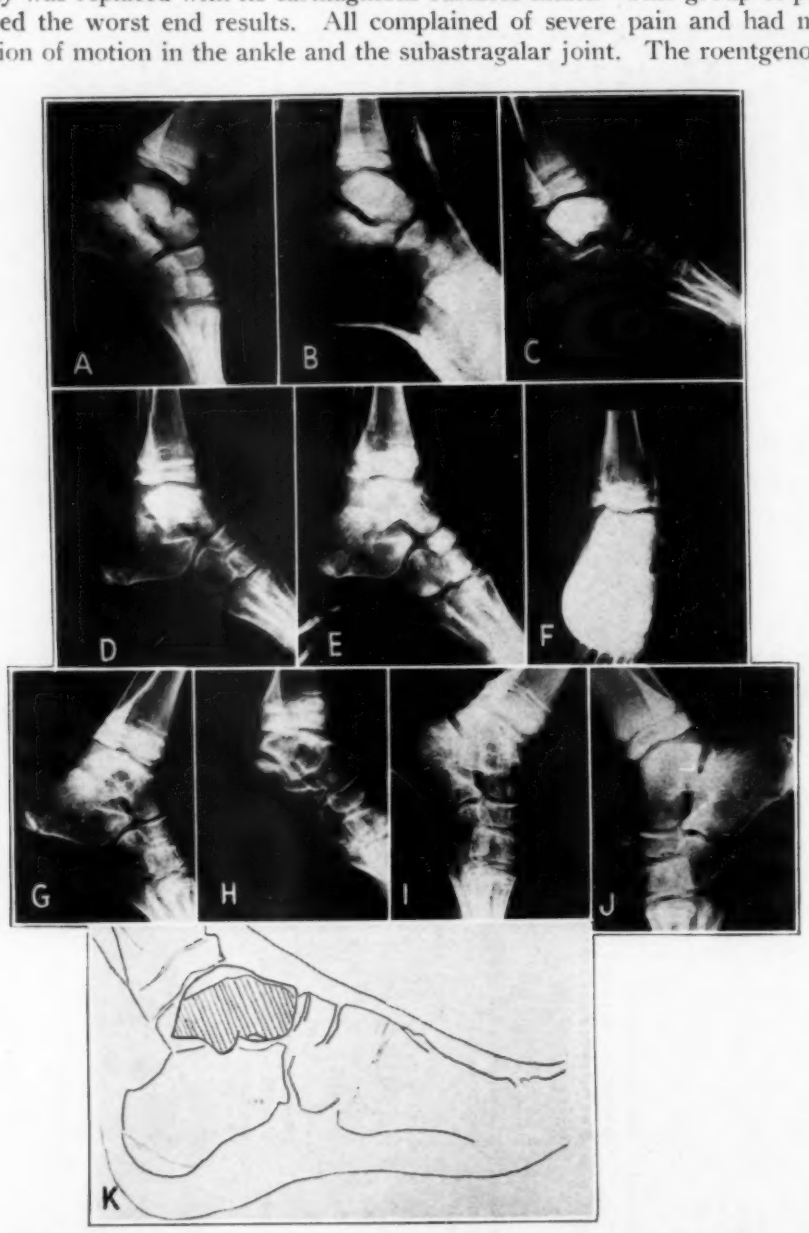

Fig. 8 (case 7).—*A*, fracture of the neck with displacement July 21, 1936. *B*, perfect anatomic reduction in cast July 27. *C*, foot eight weeks after injury (August 27). The body of the astragalus is dense; the remaining bones of the tarsus are demineralized. *D*, foot four months after injury (November 5). *E*, foot ten months after injury (May 1, 1937). There is deformation of the astragalus as well as narrowing of the ankle joint space. There is evidence of revascularization. *F*, anteroposterior view showing narrowing of the ankle joint May 1, 1937. *G*, foot eighteen months after injury (Dec. 1, 1937); further revascularization is seen. *H*, body deformed but with revascularization almost complete May 19, 1938. *I*, foot two years and six months after injury (Jan. 6, 1939). Revascularization is complete; the astragalus is deformed; the ankle and the subastragalar joint are narrowed. *J*, right uninjured foot of the same date for comparison. *K*, tracing with the left astragalus shaded superimposed on the right, showing the deformation of the bone during the revascularization.

of all revealed dense sclerosis of the body of the astragalus, marked thinning of the cartilage space of both the ankle and the subastragalar joint. Some had osteophytes on the margins of the ankle joint. Without exception, these patients were totally disabled for any activity requiring standing or walking. Case 1 is a case in point.

CASE 1 *(Fracture of Neck of Astragalus; Open Reduction, Complete Removal and Replacement of Body with Articular Cartilage Intact).*—E. J., a roofer 17 years of age,

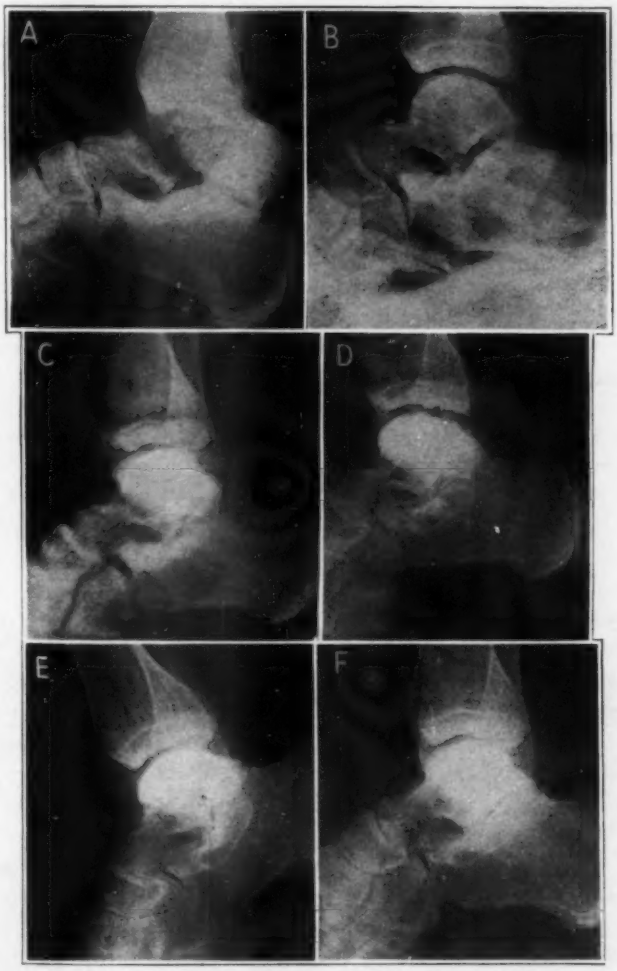

Fig. 9 (case 1).—Roentgenograms: *A*, fracture of the neck of the astragalus with posterior displacement of the body July 16, 1932. *B*, bones after open reduction and immobilization in plaster July 22. *C*, bones two months after injury (September 23). A good position is noted. The body is dense and not demineralized. *D*, bones four months after injury (November 30). The body of the astragalus is denser than the surrounding tarsal bones. The fracture line is indistinct. *E*, bones eight months after injury (April 1, 1933). There is definite devitalization of the body. *F*, bones seventeen months after injury (Feb. 2, 1934). The fracture line is not visible. There is no deformation of the astragalus. The ankle space and the subastragalar joint space are slightly narrowed. There is no evidence of revascularization of the astragalar body.

slipped from a ladder, falling 10 feet (3 meters) to concrete on July 16, 1932. Roentgenograms showed fracture of the neck of the right astragalus with marked posterior displacement of

the body. Closed reduction was attempted unsuccessfully on the day of injury. On July 22 open reduction was done. It was necessary to remove the body fragment from the ankle. The fragment was replaced with all cartilaginous surfaces intact. Convalescence was uneventful. Weight bearing was permitted six months after the injury. On Jan. 2, 1934, eighteen months after the injury, there was thickening about the ankle. Dorsiflexion of the ankle was restricted to 80/90 degrees. Plantar flexion of the ankle was restricted to 120/130 degrees; inversion of the subastragalar joint was restricted to 20/30 degrees; eversion of the subastragalar joint was restricted to 5/10 degrees. Roentgenograms showed dense sclerosis of the body of the astragalus and thinning of the cartilage space of both the ankle and the subastragalar joint. The patient complained of pain.

One patient was treated by total astragalectomy. Two years after the operation he was severely crippled and had fixed equinus deformity of the foot in spite of the fact that roentgenograms showed good posterior displacement of the foot in the ankle mortise.

COMMENT

The close parallel between fracture of the neck of the astragalus and fracture of the neck of the femur is evident. In both injuries the circulation to the proximal fragment may be and often is interrupted. Not even roentgen evidence that a fracture of the neck of the astragalus is incomplete or that the fragments are impacted gives absolute assurance of the integrity of the circulation. Aseptic necrosis of the proximal fragment will, as in the hip, occasionally result even under these conditions. With complete fracture aseptic necrosis of the body of the astragalus is the rule even though perfect anatomic reduction can be obtained and maintained by closed manipulative methods. If complete removal and complete replacement of the body are necessary because of marked displacement of the latter, death of the replaced fragment is inevitable.

The astragalus is almost completely covered by articular cartilage. On the normalcy of this cartilage depends the normal function of the ankle joint as well as that of the subastragalar joint. Articular cartilage degenerates when the bone underlying it undergoes aseptic necrosis. Thus, as a result of fracture of the neck of the astragalus, severe traumatic arthritis may develop in both the ankle and the subastragalar joint which will be relieved only by panastragalar arthrodesis. Panastragalar arthrodesis is useful but far from ideal. After a few years of usage the overstrained mediotarsal joints generally become the site of painful, disabling traumatic arthritis.

Clinical experience has proved that bony ankylosis of the subastragalar joint by itself is not disabling. For years the operation of triple arthrodesis has been carried out on feet, the articular cartilage being eraded from the subastragalar joint, the astragaloscaphoid joint and the calcaneocuboid joint. No loss of motion in the ankle results from this type of operation. If restriction of ankle motion is desired, some modification of the operation, such as posterior bone block, the operation of countersinking described by Brewster or the angular resection outlined by Lambrinudi, must be done. As a result of the use of triple arthrodesis persistent aseptic necrosis of the body of the astragalus is extremely rare and ultimate thinning of the cartilage space of the ankle does not result.

In triple arthrodesis of the foot all the conditions which are present in complete fracture of the neck of the astragalus are present. In addition, however, there is complete ablation of the articular cartilage facing of the astragalus and of that of the calcaneus, so that spongy bone approximates spongy bone. Thus the cartilage barrier to the ingrowth of new blood vessels is removed.

It is felt that the grave disability which results from severe fracture of the neck of the astragalus warrants application of a principle which has been used in

surgical treatment of the foot for many years. It is probable that early subastragalar arthrodesis, by allowing more rapid revascularization of the body of the astragalus, would salvage many ankle joints, prevent many severe disabilities and do away with the necessity for late panastragalar fusions.

SUMMARY AND CONCLUSIONS

The literature on fracture of the neck of the astragalus reveals wide divergence of opinions concerning the intrinsic circulation in this bone, the best method of treatment for this fracture and the ultimate prognosis for the injury.

Studies of the vascular system by injection are presented, which seem to indicate that the vital blood supply to the astragalus enters the neck through the superior astragaloscaphoid ligament.

The end results in 17 cases of fracture of the neck of the astragalus are presented. Attention is called to the high incidence of aseptic necrosis of the body, which leads to degenerative arthritis in both the subastragalar joint and the ankle joint and the severe disability which this produces.

Complete removal and replacement of the body with all articular surfaces intact are condemned.

Attention is called to the fact that in a high percentage of cases of incomplete fracture of the neck of the astragalus the joints will recover without disability if protected. Occasionally, however, aseptic necrosis of the astragalar body may result even under these circumstances.

Perfect anatomic reduction and maintenance of perfect position, even when accomplished by simple manipulation, will usually be followed by aseptic necrosis of the body of the astragalus and severe disability in the ankle joint and the subastragalar joint.

It is suggested that the early erasion of the articular cartilage in the subastragalar joint may, by removing the cartilaginous barrier to the ingrowth of blood vessels, shorten the period for revascularization of the body and prevent extensive degeneration of the articular cartilage in the ankle joint.

SKELETAL TRACTION AS A METHOD OF TREATMENT FOR CERTAIN FOOT DEFORMITIES

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The deformed feet which have been treated with skeletal traction include 52 recurrent club feet, 3 acquired club feet and 6 cavus feet. All the patients were children between the ages of 2 and 12 years and the deformed feet had been previously treated by various methods, with poor or inadequate end results.

In this particular age group the growth factor is important. Tissue change is rapid, and therefore any factors which tend to increase or to retard growth or to change in any way the normal direction of growth will produce a deformity.

Congenital deformities of the foot generally present a series of partial dislocations of the tarsal and midtarsal bones together with contractures of tendons and of interosseous ligaments. If these deforming factors are allowed to persist, the deformity will increase steadily with growth. The same is true of acquired deformities.

Taking into consideration the factor of growth, one may conclude that any method designed to correct these deformities should offer the least possible trauma to the involved tissues during the process of correction. The method should also insure that the correction be relatively quick and complete. Too vigorous attempts at correction may do irreparable damage to the cartilage surfaces and growth centers of the bones of the foot, and the soft tissues may be so badly torn that ruptured tendons and the resulting scar tissue may be secondary causes of deformity.

Skeletal traction as a means of correcting deformities of the feet offers a method which is relatively atraumatic and quick. The bones of the foot can be realined and the soft tissues so stretched and softened that overcorrection can be obtained with only the slightest possible pressure. The time required to achieve this varies from three to four weeks.

The successful application of skeletal traction to a foot depends on having three fixed points from which to apply the necessary push and pull to get correction of the deformity. These fixed points are obtained by inserting Kirschner wires through the tibia, the os calcis and the necks of the metatarsal bones. The wire through the tibia should be at a convenient distance from the os calcis so as to allow room for the distracting rods. It is usually inserted at the junction of the upper and middle thirds of the tibia. There should be as much bone as possible ahead of the wire in the os calcis, and the wire is therefore inserted close to the posterior superior surface. The wire through the metatarsal bones should engage all the bones, particularly the first and the fifth. These three fixed points are then joined together with distracting rods or turn buckles.

When the apparatus is correctly fitted to the foot, it is possible to apply distraction in the direction of the long axis of the foot and in the direction of the long axis of the tibia (fig. 1). In this manner the contracted soft structures of the foot and the contracted heel cord are so stretched that when the apparatus is removed no force is required to put the tarsal bones into an overcorrected position. No distraction or tension should be applied for several days after the application of the apparatus. If this principle is not followed, the patient is quite uncomfortable and there is likely to be considerable edema of the foot. At

the end of three days, when the patient has become accustomed to the apparatus, distraction is begun. This must be carried on gradually and not beyond the point of discomfort. The rod joining the wire through the metatarsal heads and the wire through the tibia is used as a stabilizer for the apparatus and not for traction or distraction except in the case of a congenital calcaneovalgus deformity. It is then used to push the forefoot into a slight equinus position. If traction is used to dorsiflex the forefoot, it is easy to partially dislocate the forefoot at midtarsus and produce a rocker foot (fig. 6*B*). Three or four weeks are required to get complete stretching. The apparatus is then removed and the foot put in an overcorrected position in a plaster cast and kept in this position from four to six months. Figure 2 shows a typical recurrent congenital equinovarus deformity before and after stretching by skeletal traction.

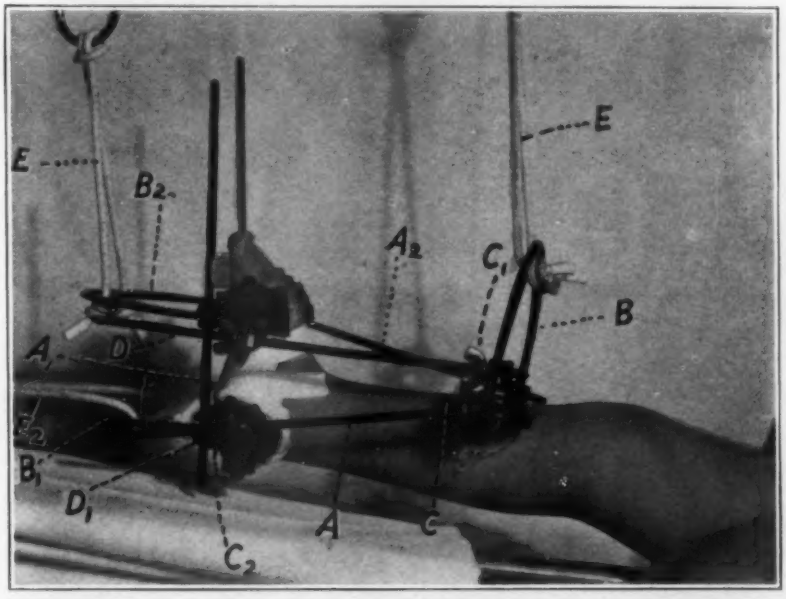

Fig. 1.—Apparatus for skeletal traction: *A*, A_1 and A_2 indicate threaded distracting rods; *B*, B_1 and B_2, horseshoes holding the Kirschner wires; *C*, C_1 and C_2, wing nuts for obtaining distraction or adjustment of the apparatus; *D* and D_1, screw nuts for controlling the distracting of the forefoot; *E*, E_1 and E_2, suspension cords controlling the entire leg while the patient is in bed.

The immediate results of the use of this method of treatment show that overcorrection of the deformity was obtained in all cases but 1. The failure in that instance was due to the fact that so much damage had been done to the bones of the foot during previous treatment it was impossible to change the fixed alinement. The end results as seen during the follow-up period were not as satisfactory as the immediate results.

Over a period of seven years it was found that 65 per cent of the recurrent congenital equinovarus feet, 50 per cent of the acquired equinovarus feet and 50 per cent of the cavus feet were completely relieved of the deformity.

Failure to maintain permanent correction of the deformity in the group of congenital equinovarus feet was due mainly to the fact that previous treatment had so damaged the tarsal bones that it was impossible to keep them in alinement as

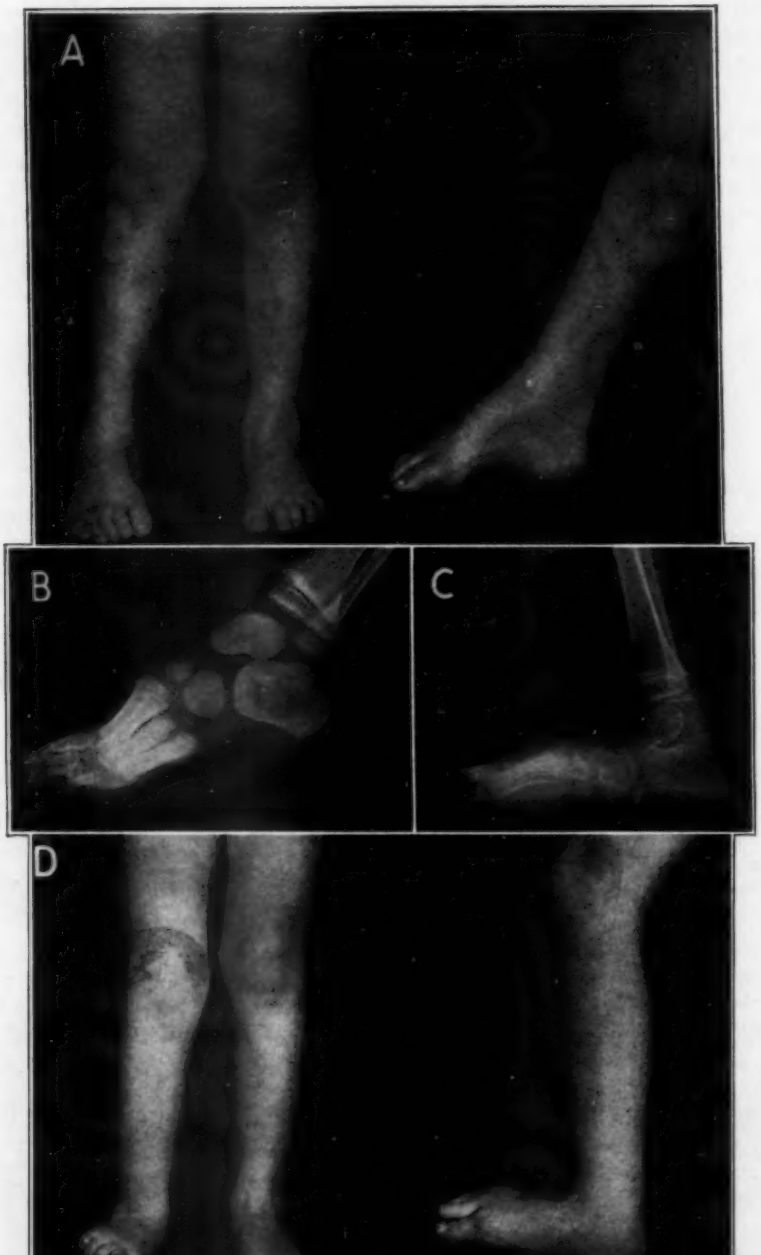

Fig. 2.—*A*, cavus foot in an equinus position with inversion of the os calcis and adduction of the forefoot. *B*, roentgenogram showing the abnormal relation between the astragalus and the os calcis. The astragalus is partially dislocated forward. *C*, roentgenogram showing the astragalus within the ankle mortise and an improved relation between the os calcis and the astragalus. The foot now has the appearance of a flat foot. *D*, right foot in a good overcorrected position.

the foot enlarged with growth. The deformity therefore slowly recurred, so that these patients subsequently had their feet stabilized by triple arthrodesis. In a small percentage of these patients the failures were due to indifferent after-care on the part of the parents and incomplete correction following stretching. In these cases restretching by skeletal traction gave complete relief from the deformity.

Fig. 3.—*A*, cavus deformity of the right foot. *B*, roentgenogram showing the cavus deformity with a moderate amount of hammer toe deformity. *C*, roentgenogram showing a flattening of the bony arch of the foot with a decrease in the hammer toe deformity. *D*, cavus deformity and hammer toe deformity entirely corrected.

In the group of acquired equinovarus feet the deformity was due to contracture secondary to anterior poliomyelitis, and the correction of the deformity was undertaken purely as a temporary measure. Correction was not difficult in this group, and the feet were held in neutral or overcorrected position until such time as

it was possible to balance the foot by muscle transplants or stabilize it by triple arthrodesis. In 1 case, however, the muscle power returned following correction, and no further intervention was necessary to maintain a well balanced foot.

Although the initial results of stretching in the cavus feet were good, the end results were only 50 per cent satisfactory. The feet in which the correction was maintained permanently were those with only a mild degree of deformity (fig. 3).

Fig. 4.—*A*, roentgenogram showing deformity of both astragali, rocker deformity of both feet and an extreme equinus position of each os calcis. This illustrates the condition of the feet after various methods of correction had been attempted. *B*, roentgenogram showing the result after skeletal traction had been used. Note that each os calcis is still in the equinus position, that the rocker deformity has been increased and that the scaphoid bone of the left foot is dislocated dorsally. The failure to obtain correction in these feet was due to the marked deformity of the tarsal bones before traction was applied.

In the cases in which the contractures were more severe, permanent correction was obtained by a combination of plantar fasciotomy and Steindler stripping in conjunction with skeletal traction.

The results of too vigorous treatment prior to the application of skeletal traction were clearly demonstrated in the group of patients in which failure ultimately led to triple arthrodesis.

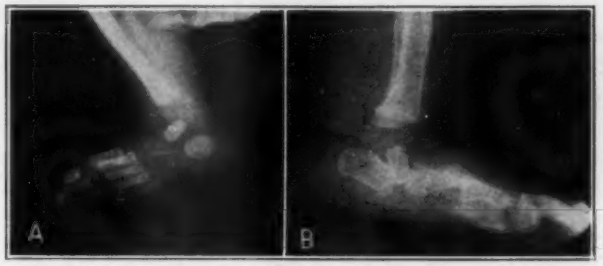

Fig. 5.—*A*, roentgenogram showing the relation between the astragalus and the os calcis prior to manipulation of the foot. *B*, roentgenogram showing dislocation of the astragalus out of the ankle mortise. The head of the astragalus is pointing toward the plantar surface of the foot. This is the result of too forceful manipulation.

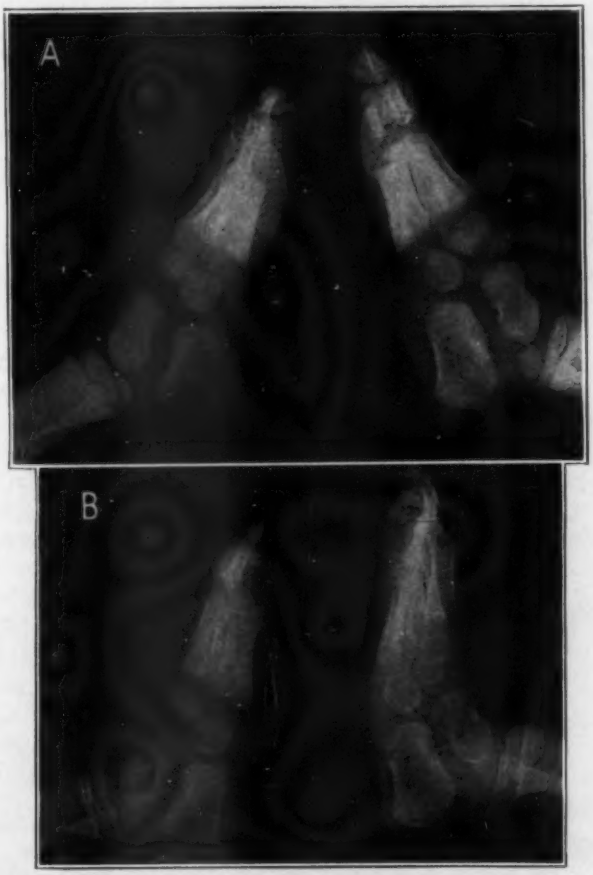

Fig. 6.—*A*, roentgenogram showing partial dislocation of the astragali of both feet. It also shows some flattening and deformity of the superior articulating surface of each os calcis. *B*, roentgenogram showing both astragali in better relation with the ossa calces. Each astragalus is within the ankle mortise. The right foot shows a mild degree of rocker deformity. This was caused by too much traction on the forefoot in dorsiflexion.

Figure 4 *A* shows the condition of a patient's feet after five and a half years of manipulation and surgical treatment. The child had had four manipulations under anesthesia induced with ether, followed by stripping of the ligaments from the medial side of the os calcis and the plantar surface of the foot. Clinical examination prior to stretching by skeletal traction showed rigid equinus and rocker foot deformities of both feet. Figure 4 *B* shows that skeletal traction failed to alter the deformity in any way, and triple arthrodesis was performed before the patient was able to walk with any degree of comfort. Figure 5 shows dislocation of the astragalus out of the ankle mortise. The head of the astragalus is directed toward the sole of the foot. The dislocation was the result of too forceful manipulation.

In every case of recurrent congenital equinovarus deformity the astragalus was shown by roentgenogram to be partially dislocated forward from the ankle mortise and the superior articulating surface of the os calcis. In many cases roentgen examination showed that the superior articulating surface of the astragalus had been flattened, with evidence of destruction of cartilage (fig. 6).

In some of the cases in which triple arthrodesis was subsequently required, it was shown at operation that the articulating surfaces of the head of the astragalus and the posterior articulating surface of the scaphoid were so deformed that it was anatomically impossible to fit them together in a stable position. This condition of the articulating surfaces cannot be demonstrated by roentgenogram, but it is believed to be one of the chief factors of recurrence after apparent complete overcorrection.

SUMMARY

Of the 61 deformed feet treated by skeletal traction, all but 1 have been successfully corrected.

Failure to maintain correction in 40 per cent of the feet treated was due mainly to gross deformity of the tarsal bones secondary to too vigorous previous treatment.

In a few cases failure to maintain correction was due to incomplete overcorrection following stretching by skeletal traction.

It is not suggested that skeletal traction in itself is a cure for deformities of the foot. It has, however, been shown that skeletal traction provides a means for overcorrecting the contractures associated with these deformities, thereby making it possible to aline the articulating surfaces of the bones of the foot in an overcorrected position with the least amount of trauma in a relatively short time.

Maintenance of correction depends on (*a*) completeness of overcorrection following stretching and (*b*) holding the foot in overcorrection for a sufficiently long period.

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SUBTROCHANTERIC OSTEOTOMY IN COXA VARA

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In the relief of many types of disability of the hip, realinement of the femur after this bone has been divided at its upper extremity in a variety of ways has been widely and increasingly practiced over more than half a century. The original subtrochanteric osteotomy of Gant became even more appreciated in England and this country through the example of its utilization set by Sir Robert Jones. At this stage of orthopedic development the simple osteotomy was limited to the rigid or presumably rigid hip with which, after division of the bone, the desired attitudinal correction could be obtained simply by realining the limb with the body.

Subsequently have come various technics for performing osteotomy under a movable hip joint, including the bifurcation operation of Lorenz,[1] the wedge resections of Pauwels [2] and Schanz,[3] later made more exactly controllable by Riedel [4] and Gaenslen [5] through the use of externally held pins, and the horizontally displacing osteotomies of Hass [6] and McMurray. All these have in common the attainment of a new axial relation between the shaft and the head of the femur for the relief of either structural instability or deformity. For the deformity of coxa vara the Riedel-Schanz procedure has come to be a technic of adequate adaptability and precision in a majority of cases.

However, it has been my experience that certain conditions are met in which this osteotomy as so far developed fails to meet the needs quite properly. Accordingly, a further technical modification has been worked out that has been so gratifying as to seem to warrant description. The two conditions encountered are, respectively, congenital coxa vara and adolescent coxa vara of high degree.

Congenital coxa vara, while not a frequently encountered condition, has been in its severe forms a rather difficult one to manage toward a satisfactory outcome. The varying manifestations of the lesion are well illustrated in the history of 3 siblings. (Incidentally, this is the single instance of siblings with congenital coxa vara in my experience.) In the first sibling the lesion was unilateral, the dystrophy or dyscrasia of the epiphysial area was mild, and by the judicious use of casts and non-weight-bearing appliances the femoral neck was carried along to approaching maturity and consolidation with only moderate varus deformity, which was quite easily offset by small wedge osteotomy; in other words, the moderate coxa vara was readily convertible to coxa valga, with termination of the difficulty.

The second sibling at the age of 8 years had acquired bilaterally a 90 degree deformity, with the epiphysial plate still much disorganized and unstable. Osteotomies decreased the deformity, but technical difficulties prevented complete conversion to coxa valga, and the deformity recurred. In such a case of bilateral deformity one may infer that surgical epiphysiodesis would have prevented recurrence, with equality of the legs in length. But it is my thesis that if in this disorder

1. Lorenz, A.: Wien. klin. Wchnschr. **49**:41, 1919.
2. Pauwels, F.: Ztschr. f. orthop. Chir. **51**:125, 1929; Der Schenkelhalsbruch, ein mechanisches Problem, Stuttgart, Ferdinand Enke, 1935, p. 6.
3. Schanz, A.: Arch. f. klin. Chir. **83**:336, 1907.
4. Riedel, G.: Zentralbl. f. Chir. **57**:84, 1930.
5. Gaenslen, F. J.: J. Bone & Joint Surg. **17**:76, 1935.
6. Hass, J.: Ergebn. d. Chir. u. Orthop. **21**:457, 1928.

the shearing strains of the position of coxa vara can be replaced by the axial stress of coxa valga, the epiphysial plate will spontaneously become stabilized and go on to normal fusion.

Sibling 3 suffered from an even greater degree of dystrophy. Though the condition was recognized and conservative treatment applied, complete solution of continuity developed in one hip, and in the other the deformity in the femoral

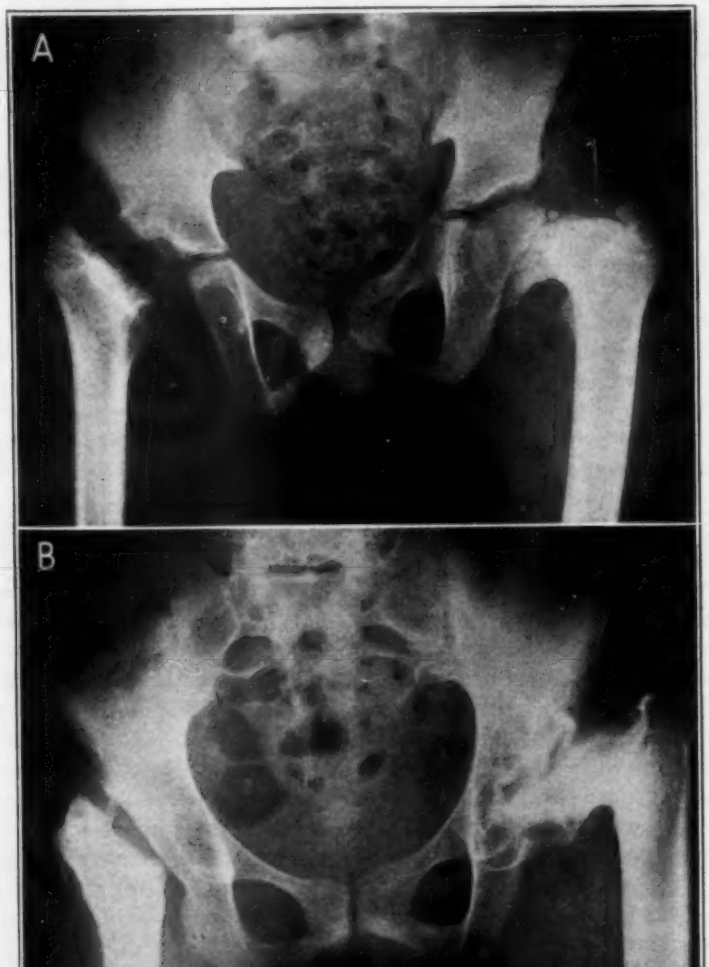

Fig. 1.—*A*, bilateral congenital coxa valga at the age of 8. A 90 degree deformity is present on the left side, with a vertical epiphysial plate, and on the right side there is dissolution of continuity, with a shadow (faint) of the undeveloped head in the lower part of the acetabulum.

B, same hip as in *A* at the end of the period of growth with practically no bearing of weight for a five year period and a Colonna type of reconstruction reported. The patient showed a bad gait, and future disability was certain. The deforming tendency in the left hip was uninfluenced by protracted abduction in a cast.

neck progressed to an acute angle (fig. 1 *A* and *B*). Both hips eventually required a pseudarthrotic type of reconstruction, with inevitably greatly impaired function.

Other instances of complete epiphysiolysis at an early age in this disorder have been encountered by me, and most surgeons will recall such instances (fig. 2).

In going over a considerable series of end results from osteotomies in cases of this condition it was quite obvious that in those cases in which the degree of deformity permitted conversion to coxa valga the difficulty was uniformly terminated, while in those in which less correction was obtained and shearing strains persisted, some degree of recurrence was the rule.

The problem, then, in severe congenital coxa vara seemed to involve (1) use of a technic preventing untoward displacement in the correction of a high degree of deformity by osteotomy and (2) stabilization of the epiphysial area at an early age. In some of the clinics where these cases have been encountered, the latter factor has logically been regarded as of primary concern, and epiphysiodesis by drilling or grafting has been the primary step, with correction of the deformity by osteotomy following later. Closure has been obtained fairly readily in the older chil-

Fig. 2.—Congenital coxa vara going on to complete dissolution of continuity at the period of adolescence. The patient went elsewhere for reconstruction. The details of the case prior to treatment are unknown, but casts were used.

dren but in the younger ones the operation has usually failed of this achievement, with consequent progression of deformity. On the other hand, evidence seems to be accumulating, as one of the illustrated cases demonstrates, that the active chondral dystrophy and instability of prenatal origin are limited to the infantile years, after which instability is residual only in the presence of shearing strains. Therefore, if the latter element can be entirely eliminated or, better still, be replaced by axial stress, the epiphysial plate can be left to mature naturally, with as much consequent contribution to length of leg as may occur, which is of more importance in the cases of unilateral deformity.

Now, with the frequent necessity of a corrective shift of the longitudinal axial relations between the neck and the shaft of up to 90 degrees, it can be seen that after division of the bone the thigh will have to be abducted to at least a right angle with the pelvis before movement of the femoral neck has been checked in the hip joint and the new alinement secured. In any but young infants this range is impossible because of soft part restriction mesially in the thigh unless such a

large amount of bone is removed in the wedge as to shorten the femur greatly and introduce the necessary slack; and with this amount of resection the instability at the site of osteotomy is too great to prevent major displacement of the surfaces in apposition.

The following approach to the problem has resulted in a technic that has proved capable of getting around these difficulties as well as obtaining any amount of

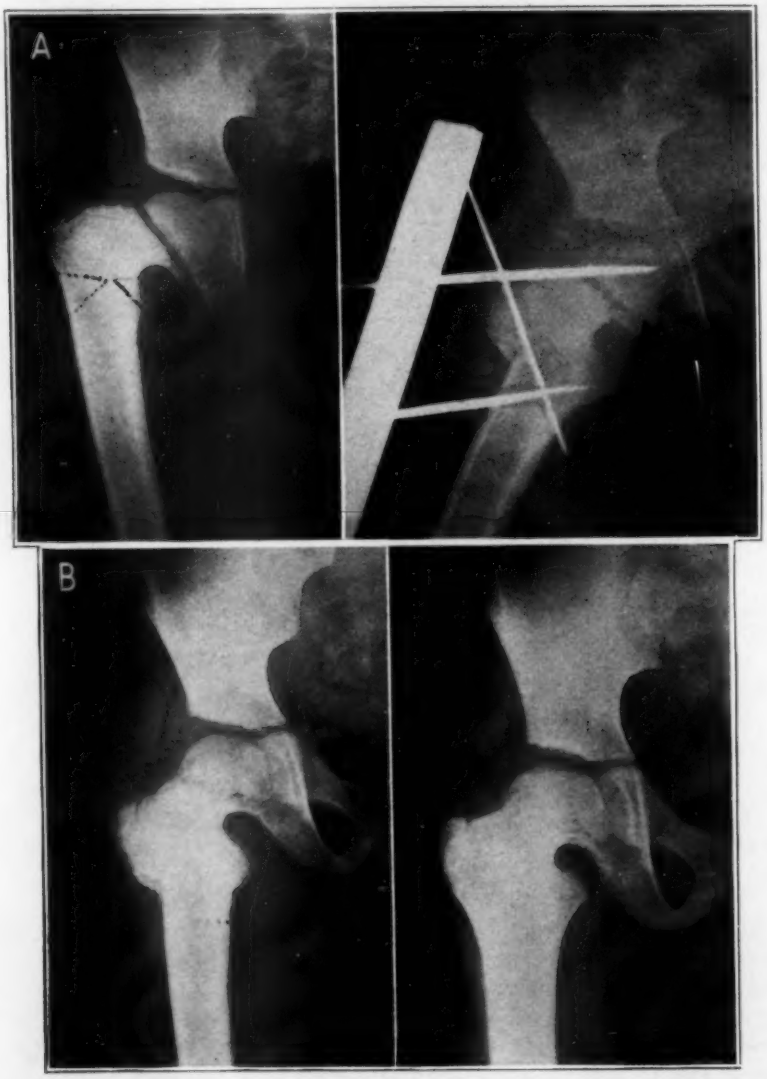

Fig. 3.—*A*, right angle coxa vara at the age of 7 years, with a nearly vertical epiphysial plate. Central pivot osteotomy was performed, with reversal to coxa valga and shift of the epiphysial plate into a position of stress—nearly transverse to the long axis of the femur.

B, the hip in *A* as seen (1) four weeks after central pivot osteotomy and (2) one year later.

reduction of the angle of deformity with no loss in length of bone or in substance. Basically, the conception is to maintain the long axis of the femoral head and neck in the normal relation to the pelvis of a nondeformed hip in the erect posture, leaving the false relation to the femoral shaft to be corrected by realinement at

the osteotomy, adding the desired increment of coxa valga. In other words, the limb would be swung, not from neutral into abnormal abduction to get correction, but from adduction into very slight abduction. Thus instead of meeting with tension from soft parts (adductor muscles) at the outset of the corrective adjustment, the whole of the latter could occur before the postural slack of the adductors was entirely taken up, and the new bone relations could be maintained during

Fig. 4.—*A*, adolescent coxa vara (old slipped epiphysis) with loss of abduction and traumatic arthritis from rim impingement: (1) preoperative; (2) following pivotal osteotomy giving restoration of a normal angle and normal articular relations without loss of length.

B, hip in *A* ten weeks after surgical correction. Abduction is two-thirds normal; internal rotation is one-third normal; external rotation is normal. There is no pain or limp or shortening. There is good stability.

healing in absence of any displacing stress or strain. Control of this neutral position of the head and neck to the pelvis could be obtained through the upper of the Riedel

pins by extending it through the trochanter into the ilium until the divergent lower pin became properly alined with it as the correction at the site of osteotomy occurred.

Now as to the modification of the osteotomy itself. It is designed, as suggested, to add no shortening or loss of substance whatever, and in consequence of the conversion of the coxa vara into a coxa valga the limb is appreciably lengthened and the preexistent shortening overcome. In fact, in a case of unilateral deformity the limb may then be slightly longer than the normal one, which is desirable, since in this disorder the capital epiphysis will mature and close somewhat prematurely anyway.

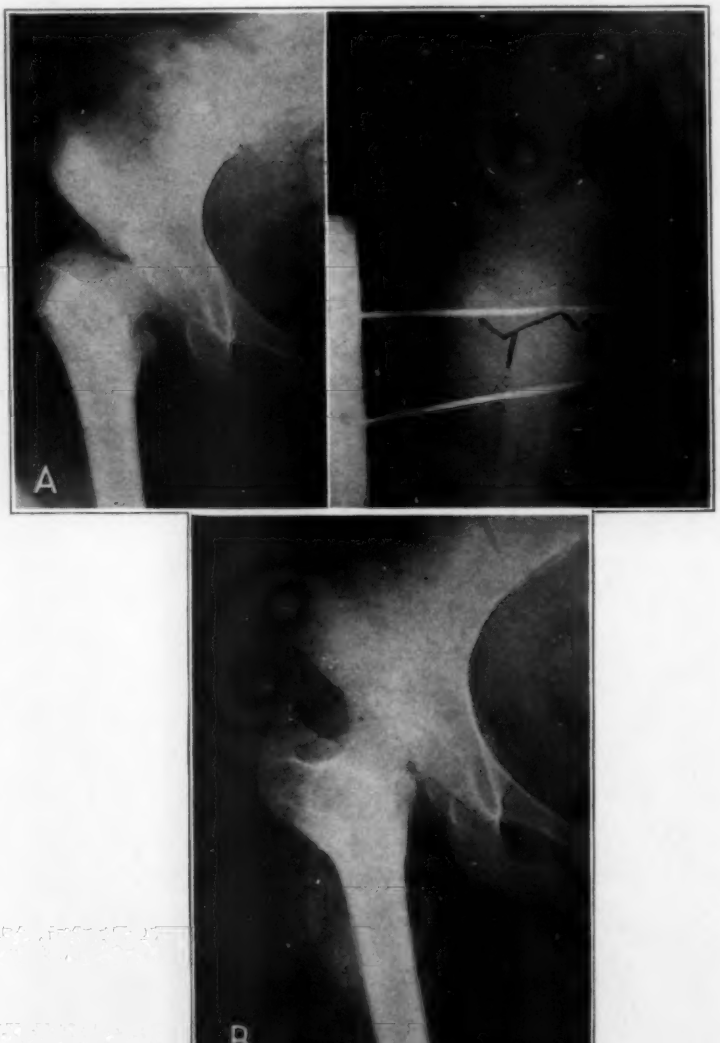

Fig. 5.—*A*, old reduced congenital dislocation with acquired coxa vara and shortening of the femoral neck and some difference in length of the leg: (1) preoperative; (2) following center pivot osteotomy with conversion to coxa valga and increase in length of the leg.

B, end result in hip shown in *A*. Note excellent clinical stability without shortening.

TECHNIC

From the usual paper pattern of the femur, the pattern of the small wedge resection and protractor patterns of the angles of the Riedel pins have been made, duplicated in tin or aluminum and sterilized with the kit. A curved incision, belly anterior, extends from over the tip of the great trochanter to the level of junction of the middle and upper thirds of the shaft. With the dissection following intermuscular planes, the vastus lateralis muscle is stripped from both the lateral and the anterior aspect, exposing the anterior intertrochanteric region from the greater to the lesser trochanter, and a curved elevator is inserted close to the latter, exposing this area at the base of the neck (fig. 3 *A*).

The next step can be done with a sharp osteotome in the case of smaller children; otherwise, with a Jones hip saw; best of all, with the Cayo stab saw (motor). A diagonal cut in the bone is made laterally and proximally from the mesial cortex at an angle of 45 degrees to the shaft, ending at or a little mesial to the midpoint of the intertrochanteric line. Guided by the metal protractor patterns the two Riedel pins are then inserted, the upper one deeply through the neck and head, the second below in the shaft. With motor saw or osteotome, the wedge is then removed laterally, but, unlike the Schanz osteotomy, the wedge resection has its apex at about the midpoint of the bone, almost meeting, at this point, the upper end of the first saw cut. The result of course is a central pivot point on which the femoral shaft moves as the thigh is abducted and the wedge resection gap is closed up, with an opening up of the mesial saw cut as this realinement is secured, but with the shaft safe against mesial displacement from the chevron-like shape of the proximal side of the osteotomy. I use a two plate clamp on the order of a woodworker's vise instead of the Riedel plate to secure the two pins in their new relations. With the osteotomy stabilized under direct vision and pin control, it has seemed advisable to back out the proximal pin until it engages in head and neck only before the clamp is applied. The removed wedge is then impacted into the opened mesial cut and the wound closed. Plaster fixation can now be applied in any comfortable position, and further abduction is neither necessary nor wise. Consolidation of the osteotomy has been seen to occur very rapidly; in a 7 year old child, in only four weeks (fig. 3 *B*).

In dealing with acquired or adolescent coxa vara, deformity of so high a degree is not often encountered; on the other hand, as these conditions are usually unilateral, and already attended by some shortening, it has seemed desirable to avoid the further shortening of a considerable-sized full transverse wedge resection and apply the pivotal osteotomy technic here too, obtaining also its security against an undesired mesial displacement of the femoral shaft in the realinement. Two illustrations of this are shown, one of an old slipped epiphysis and the other of an old reduced dislocation followed by an acquired coxa plana and abduction block (figs. 4 and 5).

SUMMARY

I have advanced the thesis that severe congenital coxa vara may be treated by converting it into coxa valga and have described a gratifyingly adequate technic for a subtrochanteric osteotomy peculiarly well adapted to securing wide ranges of stable, precise correction in this disorder and in other types of coxa vara. In arriving at this technic I have seemed conscious of the teaching and the practice of Robert Bailey Osgood in regard to methods of precision in the surgical correction of deformities of joints.

3001 West Grand Boulevard.

PAGET'S DISEASE WITH ASSOCIATED OSTEOGENIC SARCOMA

REPORT OF THREE CASES

MAURICE M. PIKE, M.D.
HARTFORD, CONN.

I propose to discuss briefly the occurrence of osteogenic sarcoma as a complication of Paget's disease of bone. I may say at the beginning that I have a vivid recollection of Dr. Harvey Cushing's presenting such a case to a group of students during a third year medical course in surgery, the site of the sarcoma being the superior aspect of the skull and the patient an elderly woman. That case was followed to its termination at the Peter Bent Brigham Hospital during the school year, and I recall that at that time Dr. Cushing advised us that sarcoma occurred as a complication of Paget's disease in 7 per cent of the cases. It is noted that Geschickter and Copeland [1] in their book "Tumors of Bone" stated that this complication occurs in from 5 to 7 per cent of cases of Paget's disease. In a recently published volume on roentgenology, the English authors Shanks, Kerley and Twining [2] stated that sarcoma is a complication in 7 per cent of the cases. Geschickter noted that the sarcoma is usually of the periosteal type and may be osteolytic, cartilaginous or osteoblastic in nature. At the Hartford Hospital from 1937 through 1941 there were 53 recorded cases of Paget's disease of bone with associated sarcoma in 4 of them. This would give an incidence of 8 per cent.

The 3 cases which I shall report and which occurred within a period of a year and a half at the Hartford Hospital show for the most part an osteolytic type of osteogenic sarcoma. All 3 patients received rather extensive treatment with roentgen rays. In spite of this, metastases and extensions occurred, and death resulted after a varying period, with an extremely uncomfortable terminal stage, in all instances.

REPORT OF CASES

CASE 1.—C. C., a 53 year old man, was referred to the hospital with symptoms related to the region of the left hip. His symptoms extended back over a period of ten months, with swelling and pain in the left leg. Previously the condition had been diagnosed as arthritis. Roentgen examination revealed Paget's disease generalized throughout the skeleton with a destructive lesion in the region of the lesser trochanter of the left femur, involving the left side of the sacrum. These findings in the pelvis may be noted in figure 1 *A*. The patient had definite secondary anemia, with phosphatase activity considerably elevated. Open biopsy of the lesion in the lesser trochanter was performed, the wound being closed without drainage. The pathologic specimen may be seen in figure 2. Multinucleated giant cells may be noted, with cells varying markedly in size and shape. The patient was given a course of treatment with high voltage roentgen rays, with which he had considerable local reaction of the skin. There was no relief from pain, and he gradually failed and died nine months after admission to the hospital or nineteen months after the onset of his symptoms.

1. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone, New York, American Journal of Cancer, 1931.

2. Shanks, L. C.; Kerley, P., and Twining, E. W.: A Text-Book of X-Ray Diagnosis, London, H. K. Lewis & Co., Ltd., 1939, vol. 3.

Fig. 1.—Roentgenograms in cases 1, 2 and 3: *A* (case 1), pelvis in Paget's disease. Note tumor of the left lesser trochanter involving the left side of the sacrum. *B* (case 2), left shoulder. Note destruction of bone in the humerus and the scapula. Note calcification within the tumor mass. *C* (case 3), right hip. Note marked destruction with large tumor mass.

CASE 2.—F. M., a man of 62 years, was admitted to the medical service of the hospital as a patient with cardiac disease and was found to have generalized Paget's disease with a tumor mass at the proximal end of the left humerus. He had complained of pain in the left arm for but one or two months but there had been pain in the chest for a period of one year. Roentgenograms revealed Paget's disease, the appearance of the skull being typical of involvement by that disease. Figure 1 *B* shows a roentgenogram of the left shoulder taken four months after the patient's admission to the hospital, revealing destruction of bone in the humerus and the scapula and a tumor mass in the supraspinatus region of the shoulder and calcification within the tumor mass. Figure 3 shows a low power projection of a

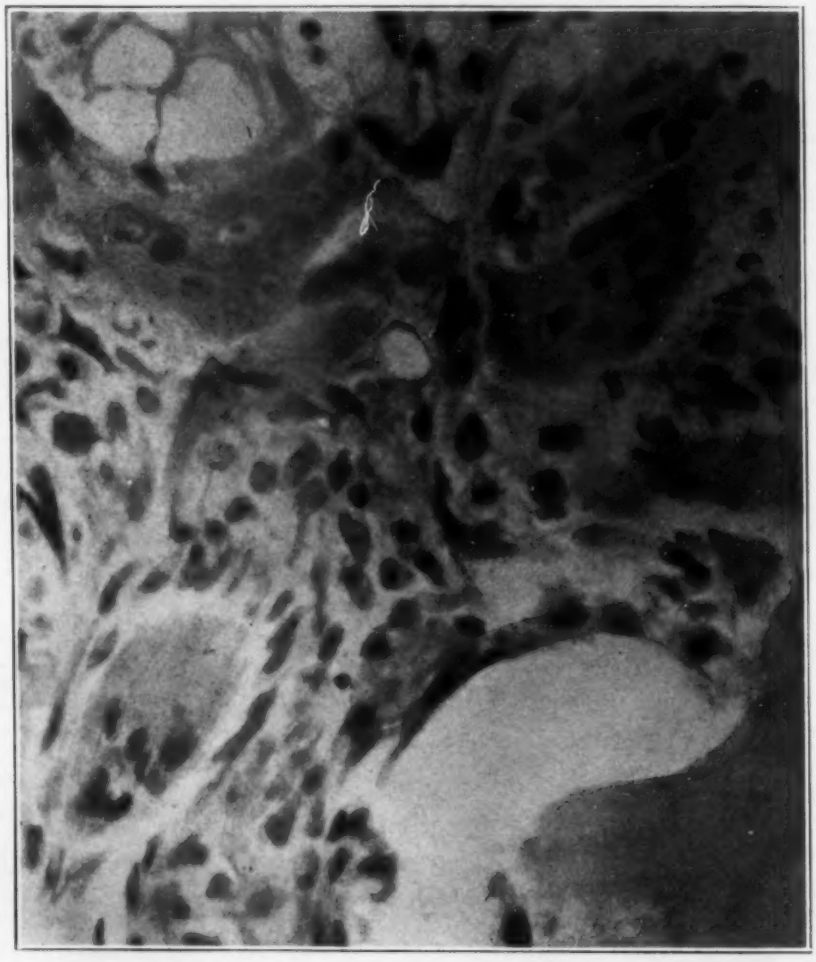

Fig. 2 (case 1).—Biopsy tissue from left greater trochanter. Note multinucleated giant cells.

section of the pathologic specimen from this patient's shoulder, revealing the occurrence of giant cells and many-shaped cells and destruction of bone all going on in the same field. This patient failed to respond to roentgen radiation, continuing to decline and succumbing eleven months after he was first seen in the hospital, fifteen months after the onset of symptoms in the left shoulder and twenty-three months after the onset of pain in the chest. There was also marked elevation of phosphatase activity. The blood levels of calcium and phosphorus were normal. There was definite secondary anemia, as noted in the preceding patient.

CASE 3.—M. E., a Negro woman of 63 years, came to the hospital because of a pathologic fracture of her right hip. She gave an interesting history of having had pain in the right leg

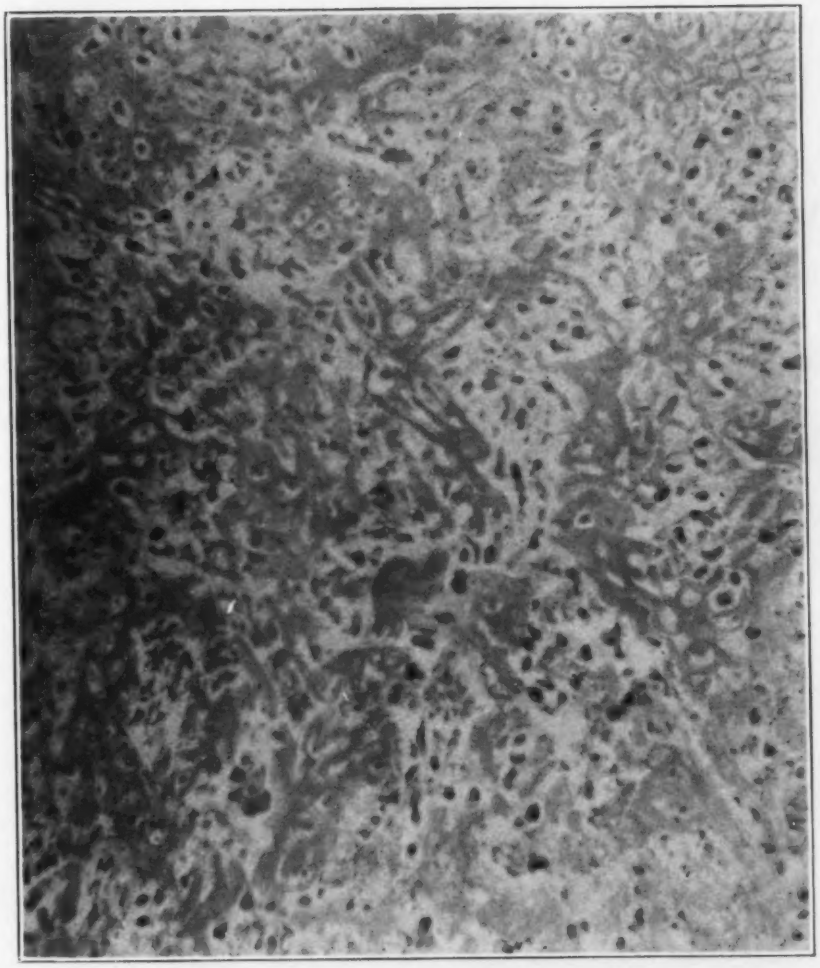

Fig. 3 (case 2).—Tissue from left scapula. Note irregularly shaped cells and giant cells with bone destruction.

for a period of a year and of having noticed shortening of this leg occurring over a period of five years. Furthermore, there was a history of a fall on this side twelve years previously. Roentgenograms revealed generalized Paget's disease. The patient was treated at first with Russell balanced traction, which was not comfortable. She was then placed in a plaster of paris spica. A roentgenogram of the right hip taken three months after her admission may be seen in figure 1 *C*, which reveals marked destruction of the bone in this region, with a large tumor mass. The patient had an extreme amount of pain. Roentgen radiation was used, and later cordotomy was performed to relieve her pain. She died seven months after admission, nineteen months after the onset of severe pain in this leg. The blood levels of

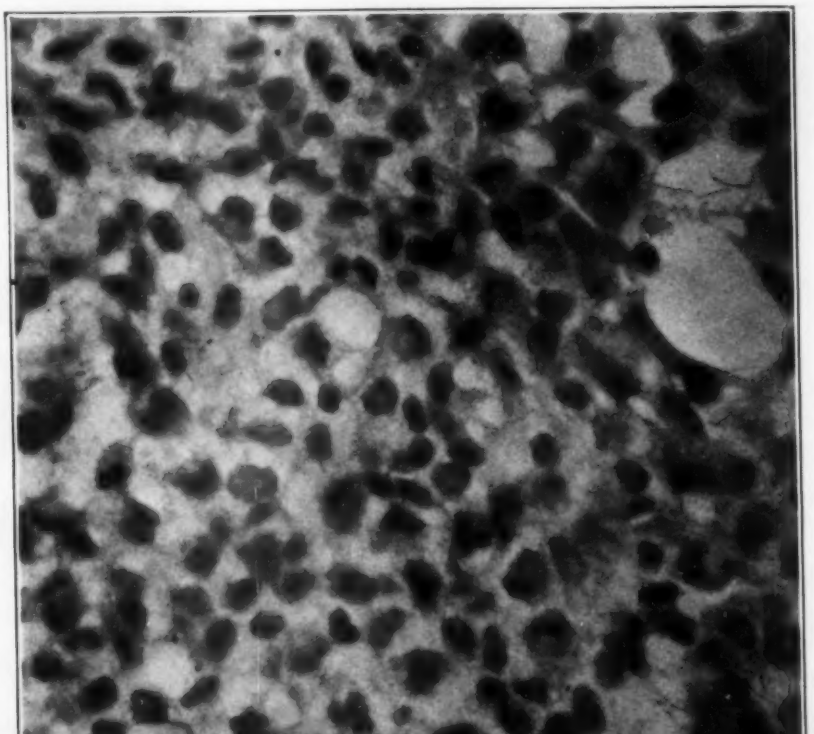

Fig. 4 (case 3).—Tissue from right hip showing very cellular tumor with giant cells.

calcium and phosphorus were normal, and the phosphatase activity was elevated. As with the others, there was associated secondary anemia. Figure 4 shows a high power projection of a section of the pathologic specimen of the right hip, revealing giant cells in a very cellular tumor.

CONCLUSIONS

Osteogenic sarcoma must be anticipated as a possible complication of Paget's disease of bone in approximately 7 per cent of the cases in a general hospital. The prognosis is universally poor, with a very disagreeable terminal stage.

179 Allyn Street.

INTERNAL BRACE FOR THE LOW PART OF THE BACK

HORACE C. PITKIN, M.D.
SAN FRANCISCO

In 1937 I briefly described an original method of surgically bracing the low part of the back.[1] The present article is written to summarize the advances in technic and the results in 53 cases in which this operation was performed in the past twelve years.

INDICATIONS FOR OPERATION

The type of back to which this operation is suited is one which shows structural instability of the lumbosacroiliac joints, singly or severally. There must not be any signs or symptoms of arthritis or tuberculosis, conditions for which the standard spinal fusion and more prolonged recumbency are indicated. Marked relaxation of the sacroiliac joints, as shown by inclinometric measurements, together with persistent sacroiliac symptoms, is a valid indication for the operation. Another indication is a persistently recurring subluxation of one or more lumbar articulations. The downward subluxations, with or without actual rupture of the intervertebral disks, are especially prone to repeated recurrence which may require internal splinting. I feel that laminectomy for removal of a ruptured intervertebral disk should be accompanied almost invariably by an internal back brace. Finally, almost all types of spondylolysis and spondylolisthesis are best splinted by this type of operation.

JOINTS THAT MAY BE SPLINTED BY THE INTERNAL BRACE

Starting with my modification of the Verrall tie rod graft, which splints both sacroiliac joints, the brace may be extended upward to include any or all of the lumbar vertebrae.

TECHNIC OF OPERATION

Given the indications noted, and disregarding all previous trials and errors, one finds that the present technic is well standardized. All subluxations and sacroiliac slips are reduced by manipulation, with or without anesthesia. Thereafter, the patient must be brought to a condition of complete comfort by rest in bed and traction. Comfort cannot always be obtained for patients who show actual impingement on nerve roots, but the more comfortable the patient becomes before operation, the more spectacular is the operative result.

After a two day preparation of the skin of the low part of the back and of both legs, the patient is anesthetized by rectal instillation of a solution of avertin with amylene hydrate and by inhalation of ether. He is placed prone on the operating table with a pillow beneath the pelvis and rolled blankets beneath the shoulders. An intravenous infusion of 5 per cent dextrose in physiologic solution of sodium chloride is started and is allowed to drip slowly throughout the operation. Each thigh is encircled by a blood pressure cuff, and the ground plate of a cautery knife is placed beneath the abdomen. Both legs and the lower part of the back are prepared and draped.

1. Pitkin, H. C.: Sacrarthrogenetic Telalgia: Plan for Treatment, J. Bone & Joint. Surg. **19**:169-184 (Jan.) 1937.

The operator identifies, by palpation, the spinous processes of the lumbar vertebrae that are to be splinted and starts the midline incision one vertebra above the limits of the brace. The incision is extended caudally to the third sacral spine, which is the one distal to a line connecting the posterior superior spines of the ilia. All bleeding of the skin is controlled by clamp and electrocoagulation. The skin is isolated by laparotomy pads and skin clips. The fat, fascia and muscles are dissected from the tips of all the spinous processes with the electrocautery knife, and the dissection is continued with a periosteal elevator until the laminas and zygapophysial articulations are exposed. If there has been any question of impingement on a nerve root, that root is exposed by lateral laminectomy of the peek hole type and is freed from all pressure.

At this point in the operation the table is broken at the level of the umbilicus to flatten the lumbar spine. With a flexible probe, the operator makes a profile of the exposed laminas from the third sacral upward to the cranial end of the brace. To fit this profile, after the blood pressure cuffs have been inflated, two curved grafts are cut from one tibia with the Cayo saw. Each graft is 12 mm. square at the cranial end and tapers to a point at the caudal end. The transacral tie rod graft is cut from the other tibia. It is 12 mm. square, and its length is equal to the distance between the sacroiliac joints at the level of the posterior superior iliac spines as measured on the anteroposterior roentgenogram. For convenience, one end of this graft is bluntly pointed, and the other end is cut squarely across. When the tibial wounds have been closed, each leg is wrapped loosely with sheet wadding and Ace bandages from the toes to midthigh, and the blood pressure cuffs are deflated.

My flat drill guide is now laid across the back at the level of the posterior superior iliac spines and is held in place by the assistant. By measuring from the center of the drill guide anteriorly to the base of the second sacral spine, the operator determines the depth at which the drill holder shall be set. The drill holder is affixed to the end of the drill guide. The drill itself is round, measures 8 mm. in diameter, has a reamer point and, at its base, swells to a recessed butt that is 10 mm. square. The drill is introduced through the drill holder at the predetermined depth into a stab wound in the buttock. By to and fro rotation, so as not to wind up the muscles through which it passes, the drill is forced in turn through the gluteal muscles, the wing of the ileum, the erector spinae muscles, the spine of the second sacral vertebra, and in the reverse order through the structures of the farther side. The drill guide and drill holder are removed, and the sharpened end of the tie rod graft is inserted into the recessed butt of the drill. With a hammer, the graft is driven through, driving the drill before it. Thus, a round hole, 8 mm. in diameter, drilled into cancellous bone, is enlarged to a 10 mm. square by the swollen butt of the drill, and then to a 12 mm. square by the driven tie rod. This insures complete solidity of the tie rod graft.

For uncomplicated cases of sacroiliac relaxation, closure of the midline incision and of the two stab wounds completes the operation. When varying degrees of lumbar instability are encountered, the tie rod functions as a foundation for the longitudinal paraspinous grafts. As already described, these two curved grafts are cut to fit the profile of the laminas from the third sacral vertebra cranially to the required distance. The pointed ends of the longitudinal grafts are inserted between the tie rod and the second sacral laminas, one on each side of the spinous process. With a Smith-Petersen graft impactor and a hammer, the grafts are driven caudally. Because of the posterior inclination of the second and third sacral laminas, the farther the grafts are driven, the more tightly their cranial

ends are approximated to the lumbar laminas. When the previously broken operating table is brought back to level, and the lumbar curve is restored, the entire brace is so tightly impacted that the operator is able to lift the patient's pelvis and lumbar spine as a unit by means of a Kocher clamp applied to any of the three grafts. Finally, the lumbar spinous processes are split longitudinally with a chisel and are turned down bilaterally to form a roof over the paraspinous grafts. It is my present practice to dust each of the wounds with powdered sulfanilamide before closure.

POSTOPERATIVE CARE

To avoid the formation of postoperative hematomas, the patient is kept supine for twenty-four hours after operation. After the first day all activity is left entirely to the patient's inclination. In this series, the shortest hospital stay was ten days, the longest was fifty-nine days, and the average was less than twenty-two days. Because of the inherent stability of the internal brace, no form of external support is needed. The surgeon should warn the patient that he may expect a slight loosening of the grafts and a feeling of instability with varying degrees of pain for a few days at about the sixth postoperative week. Thereafter, the grafts tighten up, are replaced by living bone and grow progressively larger for one to two years after implantation.

FOLLOW-UP

The longest follow-up in this series is twelve years, and the shortest is six months. With the exception of one operative death, every patient has returned to his usual or an equivalent occupation. In this series, the shortest time for return to the usual occupation or its equivalent was seven weeks, the longest was forty-eight weeks, and the average was less than eighteen weeks. One patient lost her grafts from infection, and although she continues at her usual occupation, she was not helped by the operation. In 3 patients, all women with shallow sacrums, one end of the tie rod broke out of its iliac emplacement when the longitudinal grafts were seated. In 2 of these patients a later operation produced solid union with complete relief of symptoms. The third refused a secondary operation and continues at her usual occupation unrelieved. One rather thin tie rod graft was fractured spirally by muscular effort but healed spontaneously with complete relief of symptoms.

Seventy per cent of the patients in this series had perfect anatomic and functional results. Twenty per cent of the patients were markedly improved but showed some anatomic or functional defect. In 10 per cent the results were classed as anatomic or functional failure. This series represents less than 5 per cent of the patients who were treated for similar conditions in a comparable period, since only those with the most resistant conditions came to operation.

Immediately after operation inclinometric measurements of sacroiliac mobility showed complete immobilization. At the sixth week there is moderate sacroiliac relaxation. By the third or fourth month sacroiliac motion has become and thereafter remains normal. At later operations it has been shown that this motion is allowed by torsion within the tie rod. Similarly, lateral roentgenograms of the longitudinal grafts taken in flexion and extension show no motion at first, then moderate relaxation and finally no motion. It is possible that the longitudinal grafts develop internal torsional movement, as the tie rod does, but it has not been demonstrated.

The roentgenologic follow-up is interesting. All except the 4 most recent patients have been followed for at least one year, and 2 patients have been followed

for twelve years. The dense tibial bone grafts begin to show absorption and replacement by the end of the third or the fourth month. At the end of eight months the grafts seem to have almost the same density as the surrounding bone, and reconstruction of their size and shape is evident. The tie rod now has the appearance of a doubly arched truss that is largest at its three points of bony contact. The longitudinal grafts show bulbous enlargements at all points of contact with the laminas and the tie rod. By the end of the first year replacement and growth are practically complete. In patients who do extremely heavy labor, the grafts have continued to show gradual growth for as long as ten years and appear to follow Wolff's law in response to stress and strain.

SUMMARY

An original operation is described which differs from all other types of spinal fusion in the following respects: 1. It immediately immobilizes the desired portion of the low part of the back without any form of external support. 2. It shortens the period of hospitalization to an average of approximately three weeks. 3. It shortens the period of partial disability to an average of approximately eighteen weeks.

Fifty-three patients who were operated on after this method have been followed for from six months to twelve years.

909 Hyde Street.

AN OPERATION FOR BENIGN CYST OF THE UPPER HUMERAL METAPHYSIS

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BOSTON

A benign cyst (osteitis fibrosa cystica localisata) of the upper end of the humeral shaft may be so large that fixation following curettage and packing with bone presents some difficulties, especially when the wall of the cyst is very thin and fracture is present or imminent.

Two such cysts were recently dealt with by me in a manner which I have not seen described heretofore. The method is presented because it seemed to meet the requirements, mechanical and therapeutic, in a satisfactory manner.

In each case (figs. 1 *A* and 2 *A*) the cyst was approached anteriorly, the biceps muscle being reflected medially, the deltoid muscle laterally. The periosteum was carefully reflected medially and laterally to a point about 3 cm. below the distal end of the cyst. A vertical slot was made in the anterior wall of the cyst, exposing the interior, and through this the fluid and the lining membrane were removed.

Two full cortical thickness grafts were removed from the tibia, each being equal in length to the length of the cyst plus about 3 cm. and about 1 cm. wide.

Two transverse slots, one on each side, were then made in the wall of the cyst at the level where the shaft flares out abruptly to meet the humeral head and tuberosities. This level normally is about 4 cm. below the tip of the greater tuberosity; in benign cysts it will vary. Through these slots the two grafts were pushed well up into the interior of the cyst to the latter's proximal limits, toward (but not through) the upper epiphysial plate. The lower portions of the grafts lay outside and snugly against the cortex of the shaft distal to the slots, extending downward to a point about 3 cm. below the cyst.

Two transfixion screws of vitallium or stainless steel were then introduced through transverse drill holes made in the grafts and the normal shaft immediately distal to the cyst. These screws fixed the grafts. The grafts in turn provided stout fixation, in normal relationship, of the epiphysis and the shaft, and at the same time served as bone packing.

In what remained of the cyst chamber were placed a few sizable free bone transplants.

So stout was this fixation in each case that no external splint was necessary. The extremity was suspended from the Balkan frame by the Blake method for one to three weeks, until wound healing was advanced. Both boys were then ambulatory with no other support than an arm sling for eight weeks.

Adequate bony reorganization within the cyst was thought to be established beyond doubt in each case in three months. See figure 1 *B, C* and *D* and figure 2 *B* and *C*. When the patient in each case was last seen five months after operation, there was a normal range of motion without pain throughout the extremity, and obliteration of the cyst seemed complete.

266 Beacon Street.

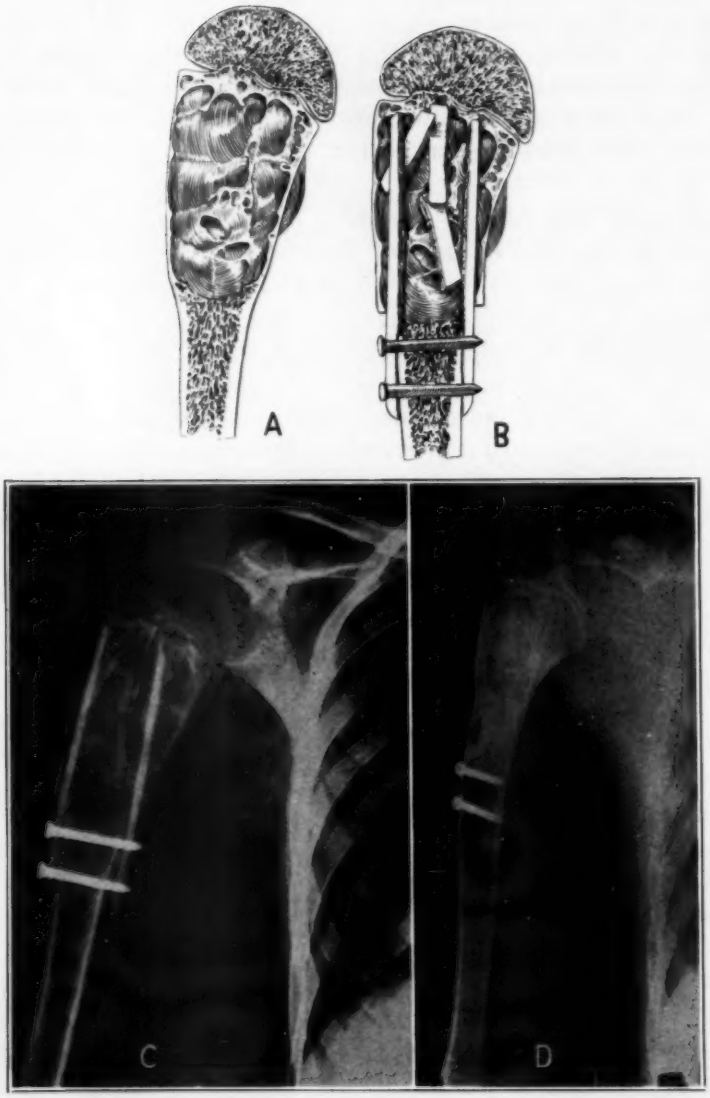

Fig. 1 (case 1).—*A*, artist's drawing of the cyst, made before operation. (The original film has been mislaid; the pathologist's report was bone cyst.) The patient, a boy aged 14, had had three fractures in the past eighteen months. *B*, schematic drawing to illustrate the operative procedure. See text for a detailed description. *C*, roentgenogram made shortly after operation. *D*, roentgenogram made eight months after operation, showing almost complete obliteration of the cyst by bone.

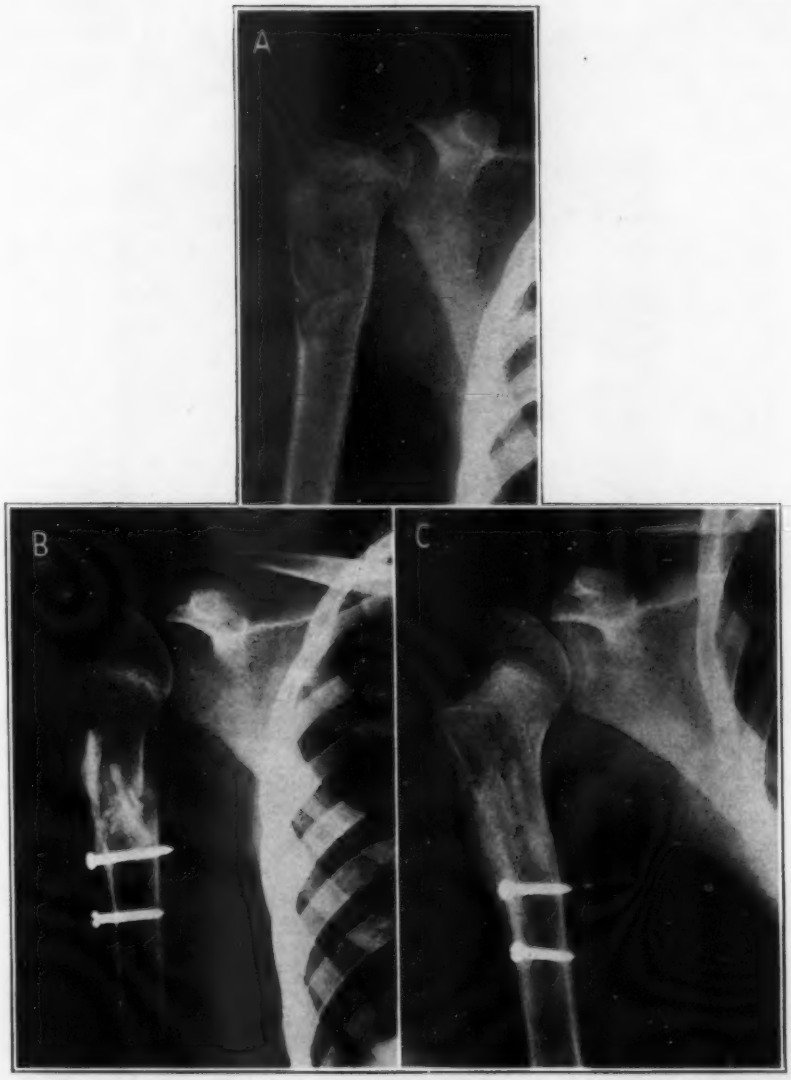

Fig. 2 (case 2).—*A*, osteitis fibrosa cystica. The patient, a boy aged 13, fell, fracturing the humerus through the cyst four days before admission. *B*, roentgenogram taken shortly after operation. One strut was used instead of two. *C*, roentgenogram taken five months after operation, showing almost complete obliteration of the cyst by bone.

AN OPERATION FOR CORRECTION OF RECURRENT DISLOCATION OF THE JAW

LEMUEL D. SMITH, M.D.
MILWAUKEE

As a variant to the procedures of either injection of the capsule or removal of the discus articularis for recurrent dislocation of the jaw, I have come to prefer the following procedure as more positive than the first and simpler and more positive than the second.

Fig. 1.—One-inch (2.5 cm.) incision made 1 inch in front of the external meatus of the ear.

A vertical 1-inch (2.5 cm.) incision is made about 1 inch anterior to the external meatus of the ear as shown in figure 1. The skin here tends to form vertical folds. If the closure is skilfully done the scar is hardly discernible. This line will correspond to the anterior border of the condyloid process of the mandible with its upper limit over the tubercle of the zygomatic process of the temporal bone. A speculum retractor (*a* in fig. 2 *A* and *B*) is pushed into the wound along and touching the anterior border of the neck of the mandible until it is stopped by the tuberculum articulare of the temporal bone. Through the speculum a $\frac{9}{64}$ inch (0.35 cm.) drill (*b* in fig. 2 *A*) is introduced. It will impinge on the tuberculum articulare. The drill is held in the frontal plane and is directed cephalad

at an angle of 45 degrees. The drill is sunk until it pierces the inner table of the temporal bone. The bone is 5/16 inch (0.08 cm.) thick here. The drill hole is tapped with tap *c* (fig. 2*A*). A shoulder bone peg 19/64 inch (0.39 cm.) (*d* in fig. 2*A*) is then screwed into the hole until it breaks off at *e* (fig. 2*A*), which leaves a bone plug (*f* in fig. 2*C*) projecting ¼ inch (64 cm.) from the tuberculum articulare as a buffer against which the condyloid process of the

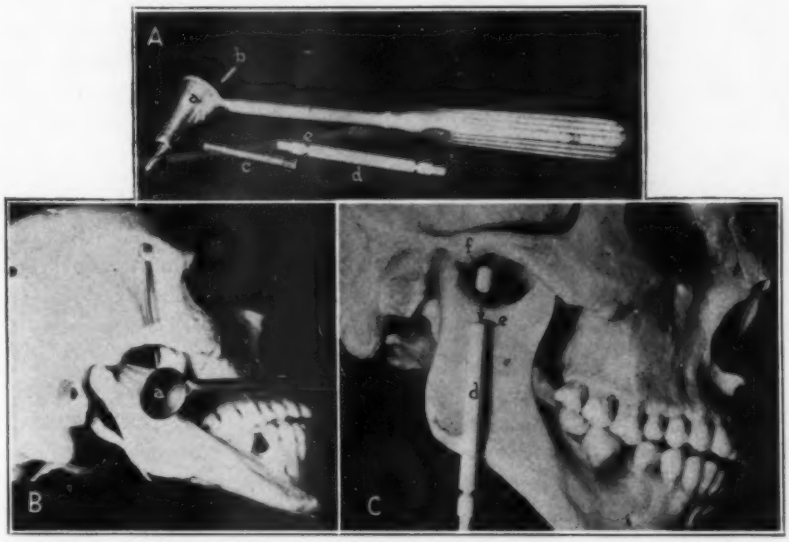

Fig. 2.—*A*, tools used in the operation: (*a*) speculum retractor; (*b*) drill; (*c*) top; (*d*) bone peg; (*e*) breaking point of peg. *B*, insertion of speculum retractor (*a*). *C*, bone plug left after breaking off of bone peg *d* at *e*.

mandible will impinge. On removal of the speculum the wound closes spontaneously. The skin is sutured with horsehair. The scar is negligible.

Effective hemostasis is important. The only complication that has occurred was temporary partial paralysis of the facial nerve, which disappeared with absorption of the hematoma.

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USEFUL SURGICAL PROCEDURES FOR RHEUMATOID ARTHRITIS INVOLVING JOINTS OF THE UPPER EXTREMITY

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"Wait until the acute condition quiets down." "Don't operate during the acute stage." These statements express the commonly accepted opinion about surgical procedures undertaken during the active stage of rheumatoid arthritis. The lack of success of fascia lata arthroplasty and of synovectomy when undertaken during the acute stage is the obvious reason for this prevailing opinion. The success of vitallium mold arthroplasty undertaken in spite of active disease has made us stop to analyze the pros and cons of operative treatment.

To relieve pain, to arrest the disease process and to preserve function are the aims of treatment of any acute condition of a joint. "Rest" is the principle of all so-called "conservative" nonoperative measures. As a rule, the "rest" treatment is successful in relieving pain, sooner or later; as a rule, the "rest treatment" is successful in arresting the disease process locally; when it comes to preserving function, the "rest" treatment is generally unsuccessful; this is particularly true since it affects not only the primary joint but also the other joints of the extremity, rendering them more vulnerable to the disease process. If it were possible to put one joint at rest without affecting the other joints of the extremity, the "rest" treatment might be justifiable, but when putting one joint at rest jeopardizes the function of the other joints, the treatment becomes questionable. A joint immobilized or put at rest in a plaster cast becomes less painful because acutely inflamed, congested structures are prevented from performing their function; nature is partially successful in bringing about this same result by its own method of immobilization, that of muscle spasm. Neither method is ideal; both have distinct drawbacks.

Nature's "protective muscle spasm" is the gentlest, mildest form of immobilization; it diminishes pain by diminishing function and by putting the affected joint in a position of minimum discomfort. This position is rarely, if ever, the optimum functional position and consequently must not be allowed to persist for a long enough time to produce a lasting deformity of the joint involved as well as of the other joints of the extremity; one must recognize the fact that as soon as one joint of an extremity is put into a position of deformity, the other joints of that extremity are made to function in a corresponding, proportionate position of deformity. The first objection to immobilization by protective muscle spasm is the position of deformity involving not only the primary joint but also the other joints of the extremity.

Muscle spasm affects the circulation, both arterial and venous; it diminishes the arterial circulation of all the muscles in spasm as well as that of all the structures distal to it; it interferes with the venous return, causing congestion and

edema of all the structures distal to the region of spasm. The second objection to immobilization by muscle spasm is the interference with circulation, diminishing nutrition to other joints and rendering them more vulnerable to disease.

Muscle spasm interferes with the motion between muscles, between muscles and fascia and between muscles and underlying bone; it creates increased tension and friction, resulting in fascitis and bursitis. These conditions in themselves may be productive of greater pain than the condition of the joint primarily affected and thereby delay the return to function. Bursitis and fascitis, then, represent still further objections to immobilization by protective muscle spasm.

Atrophy of muscles, ligamentous loss of elasticity, atrophy of bone represent other complications of immobilization by protective spasm of muscles; they also complicate artificial immobilization by means of plaster casts, braces or other means of partial or complete elimination of function.

Artificial immobilization relieves pain by partial or complete elimination of function; it also attempts to avoid one of the complications of immobilization through spasm of muscles by putting the joint at rest in the optimum functional position. This is not altogether desirable since it subjects the articular surfaces to continuous apposition, one surface being forced against the other by the resistance of the controlling muscles. The effect is distinctly less noticeable in cases of immobilization by traction, but even this form of treatment has some of the unfavorable pressure aspects. Joint surfaces exposed to continuous apposition and pressure, one against the other, instead of the normal intermittent pressure and friction, undergo degenerative changes more quickly than if they were allowed at least partial function. This must be kept in mind and immobilization necessary for the relief of pain made use of for the shortest possible period. Any secondary source of pain must be avoided by eliminating prolonged immobilization.

The active, or muscular, support and the passive, or ligamentous, support of a joint undergo changes characteristic of the tissues of which they are composed when they are deprived of their function. Muscle fibers atrophy in proportion to the length of time that they are forced to remain at rest; such atrophy is accompanied by loss of elasticity on the part of the fibrous tissue framework. These changes represent distinct obstacles to restoration of function. The passive supporting ligaments normally have a certain amount of elasticity, but it is slight in comparison with the muscular elasticity. When they are deprived of their function, their elasticity is diminished and they become structures very resistant to restoration of motion in the joint which they support.

Atrophy of bone represents the final objection to prolonged immobilization. Whether or not such atrophy is a source of pain, we are unable to say, but that is a possibility. There can be no question, however, that it renders surgical restoration of function more difficult. Keeping in mind that a joint represents the fulcrum through which the controlling muscles exert their leverage, it is clear that postoperative exercises, aiming to restore muscle power and overcome inelasticity, will tend to force the newly created joint surfaces against one another; in the presence of atrophy of bone such postoperative treatment will tend to distort the potential joint, which consequently will have a diminished range of motion.

We have presented some of the main objections to conservative treatment by immobilization. We do not mean to imply that immobilization is never indicated; it is indicated for relief of pain but should never be carried to a point where it creates obstacles to successful surgical treatment. One must constantly be on guard against carrying the treatment to a point productive of secondary sources

of pain, such as bursitis and fascitis. If such secondary conditions do arise, they must be eliminated, so that the functional treatment of the primary condition can be undertaken at the earliest possible moment.

Functional treatment, aiming to relieve pain by medication, is distinctly more desirable, but even such treatment can be carried to a point creating conditions difficult for the surgeon to overcome. The internist and the surgeon are apt to wait for the roentgenograms to show advanced destructive changes before resorting to operative treatment. It is only in retrospect, when they see local deformity, as well as deformity of other joints secondarily involved, that they say, "We should have operated at an earlier stage and thereby prevented these deformities; now we have to correct them."

Rheumatoid arthritis involving any one of the joints of the upper extremity brings on protective muscle spasm producing a position of deformity which is essentially the same, no matter which joint is involved. The position of deformity of the shoulder is one of adduction and internal rotation; that of the elbow is one of flexion accompanied by diminution of motion in pronation as well as in supination; that of the wrist is one of diminished dorsiflexion accompanied by ulnar deviation. Limitation of pronation and supination at the wrist is, of course, dependent on limitation of these same motions at the elbow and vice versa. The small joints of the hand gravitate in the direction of ulnar deviation and flexion. Since one painful joint is apt to result in limitation of motion of all the other joints, with all the evils that accompany such limitation, it is important to mobilize the joint primarily involved as soon as possible and not delay the return of function of the joints secondarily involved any longer than absolutely necessary. With this in mind one must continually be on the lookout for a change in the pain or discomfort produced by the primary lesion. The shoulder joint is a good example of what we mean by this statement. Rheumatoid arthritis involving the glenohumeral joint results in a position of adduction and internal rotation of that joint. The muscle spasm producing this position affects not only the joint itself but also the subacromial and subdeltoid bursas, and these structures become involved early in the inflammatory process. Since scapulothoracic motion to a considerable extent depends on locking of the glenohumeral joint, and since locking of the glenohumeral joint produces increased tension of the subacromial bursa, an acute inflammatory condition of the subacromial bursa automatically eliminates scapulothoracic motion. In other words, subacromial bursitis accompanying rheumatoid arthritis of the glenohumeral joint practically eliminates function of the shoulder and secondarily of the entire upper extremity. In order to restore function, the pain arising from the subacromial bursitis must be eliminated; we have found the operation of acromioplasty a satisfactory procedure for this purpose. By excision of the acromion the central tendon of the deltoid muscle is brought into apposition to the scapulohumeral tendinous cuff and it is this relationship which brings about relief from pain and allows the patient to make use of whatever motion there is in the scapulohumeral joint and to compensate for the diminished motion in the scapulohumeral joint by scapulothoracic motion.

ACROMIOPLASTY

The first operation of acromioplasty was performed in September 1935 for the relief of pain arising from the impinging of an exostosis of the anatomic neck of the humerus on the acromion. Excision of the acromion enabled the patient to make use of her scapulothoracic motion and improved the glenohumeral motion also, although not markedly. The striking effect was the improvement in function

of the entire upper extremity because of the elimination of pain. This is now seven and a half years ago and the patient has remained comfortable and able to use her upper extremity for practically all routine activities. Since that time the operation has been performed on 11 patients, all with rheumatoid arthritis—unilaterally in 8, bilaterally in 3. The results have been satisfactory in practically all the cases. When we say "satisfactory," we refer particularly to the relief from pain; there has not been any striking increase in the range of motion in the glenohumeral joint. The improvement in function has in all cases been due to improvement in compensatory scapulothoracic motion. These 11 cases were all instances of rheumatoid arthritis, and the operation was not undertaken in a single instance until there were advanced changes in the glenohumeral joint. Since the operation is not a destructive procedure, it seems reasonable to suggest that it be undertaken as soon as the diagnosis of subacromial bursitis is made, even though the roentgenograms do not show an advanced destructive process in the glenohumeral joint. We are confident that if the operation is undertaken early, even better functional results may be obtained.

Operative Technic.—Various incisions have been used. The S-shaped or bayonet incision has been found the most practical; it starts at a point ¾ inch (2 cm.) anterior to the anterior angle of the acromion and extends to a point ¾ inch posterior to the posterior angle of the acromion. The insertion of the trapezius muscle is defined from the origin of the deltoid muscle and the periosteum between these muscle attachments incised. The deltoid muscle is reflected from a point just lateral to the acromioclavicular joint to a point just mesial to the posterior angle of the acromion. By this reflection of the deltoid muscle the subacromial bursa is exposed. A tape or a small sponge is passed under the acromion and the acromion excised by means of an osteotome. The acromioclavicular joint should be left intact; the posterior angle of the acromion should be included in the excision. The subacromial bursa, now completely exposed, is commonly found filled with congested villi covering the underlying tendinous cuff. As complete a synovectomy as is indicated by the findings should be carried out.

There is one important point to be observed in the closure of the wound; that is the careful approximation of the central tendon of the deltoid muscle to the periosteal attachment of the trapezius muscle. By reflecting the periosteum to which the trapezius muscle is attached, i. e., from the acromioclavicular joint to the spine of the scapula, a better approximation is achieved.

This operative procedure aims to relieve pain arising from the secondary lesion, that of subacromial bursitis. On eliminating this source of pain better function can be expected on the part of the joint involved primarily, i. e., the glenohumeral joint, as well as improvement in compensatory motion between the scapula and the thorax.

EXCISION OF THE HEAD OF THE RADIUS

Rheumatoid arthritis involving the elbow joint results in limitation of flexion and extension as well as pronation and supination. The radial head plays an important part in all motions of the elbow; consequently if one can eliminate pain associated with function on the part of that structure, one can expect a distinct improvement in the function of the elbow joint as a whole. The biceps muscle is the one involved in protective muscle spasm to a greater extent than any other muscle; because of the spasm of this muscle, extension and pronation are affected early in the disease process. At operation we have repeatedly observed a discrepancy in alinement between the radial head and the capitellum; we have found

the radial head lifted upward in such a way as to prevent it from moving in a correct mechanical fashion over the congruous surface of the capitellum. We have found in the articular surface of the capitellum a sulcus or a depression corresponding to the inferior articular margin of the radius. This joint defect is comparable to the joint defect in the femoral condyle produced by the articular margin of the tibia in spasm of the hamstring muscles.

The natural answer to the mechanical interference with flexion and extension as well as pronation and supination is excision of the radial head. There is no need of dwelling on the details of this procedure since it is a generally accepted operation for relief of any condition interfering with normal function between the radius and the ulna or the radius and the capitellum. The operative findings have been instructive since they have been decidedly comparable to the changes in the subacromial bursa in rheumatoid arthritis. Synovial villi frequently herniate through the incision into the articular capsule; they arise from the synovia and are eliminated during the second stage of the operation, that of partial synovectomy. The villus formation may at times be so extensive as to make desirable extending the synovectomy to the pouch of the triceps muscle; this can be done by reflecting muscular attachments posteriorly from the epicondylar ridge. The objection may be raised that since this operation consists not only in excision of the radial head but also in a rather extensive synovectomy, the beneficial results may be accounted for on the basis of the synovectomy rather than on the basis of the excision of the radial head. When we first undertook this operation, the synovectomy was decidedly incidental, but even so good results were obtained. In cases in which the more extensive synovectomy seems indicated, there can be no question that this part of the procedure is distinctly helpful; it would not be constructive, however, if undertaken without the excision of the radial head—as a matter of fact, it would not be technically possible.

Excision of the radial head has been performed in 10 patients, in 5 bilaterally and in 5 unilaterally. Again the results have been striking as far as relief of pain is concerned. The motion in flexion and extension has not been markedly improved, but it has been benefited; the outstanding benefit has been the improvement in pronation. We have no patients sorry that the operation was performed; they are all grateful for the relief it has afforded.

Again it seems right to point out that the earlier this operation is performed, the better the functional result. In our series the operation has not been performed until the roentgenograms showed advanced destructive changes involving all the joint surfaces.

ARTHRODESIS OF THE WRIST; EXCISION OF THE DISTAL END OF THE ULNA

In 1936 William Darrach [1] published an article on excision of the distal end of the ulna for relief of pain arising from faulty mechanics of the wrist secondary to fractures of that region. Based on this article, a new approach to the wrist joint was developed.[2] Arthrodesis performed through this approach has been particularly satisfactory because of the excision of the distal end of the ulna; this preserved whatever motion there was in pronation and supination and in some

1. Darrach, W., in Libre jubilaire offert au docteur Albin Lambotte par ses amis et ses élèves, Brussels, 1936.

2. Smith-Petersen, M. N.: A New Approach to the Wrist, J. Bone & Joint Surg. **22**:122-124 (Jan.) 1940.

cases improved the range of motion. The dorsal approach to the wrist is very satisfactory and excellent results are obtained as far as fusion of the radiocarpal joint is concerned, but, since the ulna is left intact, motion in pronation and supination does not benefit. When one has a disease process to deal with, as one has in rheumatoid arthritis, it is particularly important to eliminate pain arising from the radioulnar joint, and this can be accomplished only by excision of the distal end of the ulna.

Arthrodesis has been done through this approach in 5 cases, with relief from pain and preservation of motion in pronation and supination. In 4 cases the distal end of the ulna was resected without fusion of the radiocarpal joint, since this joint was not involved to such an extent that fusion seemed justifiable. It does not seem fair to pass judgment on an operative procedure on the basis of 4 cases only; it is our impression that the patients who had excision of the distal end of the ulna plus arthrodesis of the radiocarpal joint have done better than the patients who had excision of the distal end of the ulna alone.

METACARPOPHALANGEAL AND INTERPHALANGEAL JOINTS

The metacarpophalangeal and interphalangeal joints may be involved in the disease process of rheumatoid arthritis primarily, or they may become involved secondarily to disease of one of the major joints of the extremity; in either case disalinement, flexion, subluxation and ulnar deviation occur relatively early. We say "relatively early" because we are unable to give a definite estimate of the time element, but we are anxious to emphasize the danger of the joints becoming involved from the very first. Obviously, the reason for this threat to the function of the hand is the force of gravity. The minute any joint of the upper extremity is involved in a disease process protective muscle spasm puts it in a position demanding defense against the deforming force of gravity. Since the force of gravity is active continuously but the defense is not, deformity is the result—a deformity which is difficult, sometimes impossible, to correct. The natural conclusion is that no pathologic condition of a joint must be allowed to persist for a time long enough to give gravity a chance. If operation is undertaken early, eliminating pain arising from one of the major joints of the upper extremity, the smaller joints will continue to function and thereby be able to survive without being destroyed by the disease process. We cannot prove that this is so; we submit it for consideration and analysis, along with suggestions made for early operative treatment of the larger joints of the upper extremity.

SUMMARY

Reasons have been advanced for undertaking early operative treatment of rheumatoid arthritis in spite of active disease. Early operative treatment is urged in order to prevent the rise of secondary sources of pain. We urge conscientious analysis of pain complained of so that surgical treatment can be undertaken if the character of the pain changes, since this may be indicative of what we choose to call secondary sources of pain. If there is evidence of bursitis or fascitis, the advisability of surgical treatment of so-called secondary sources of pain must be seriously considered. The point that we are most anxious to bring home is early surgical treatment before destruction of the joint is too far advanced to allow maximum benefit from the operation.

The operative procedures suggested—acromioplasty, excision of the head of the radius and excision of the distal end of the ulna, with or without arthrodesis of the wrist—are constructive procedures. It is hardly fair to call them minor, since that will immediately bring about a diminished respect for them. Let us refer to them as being constructive procedures for use before the disease process is far advanced. We feel justified in recommending them because they have given satisfaction to the patients and to the surgeon. The surgeon has been satisfied because of the relief of pain in spite of the fact that the range of motion has in no case been strikingly improved.

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POSITIONAL PAIN

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Pain arising from bodily positions must be distinguished from postural discomfort. Posture, physiologically speaking, is the *active* maintenance of an animal's station in its environment. It is a manifestation of muscular activity sustained largely by proprioceptive reflexes in accordance with inherited nervous patterns, modified by social customs and personal approbations or taboos. It connotes resistance to external forces, such as air currents and gravity. Position, on the other hand, is imposed on a part, and the station is maintained by *passive* factors. It connotes relaxation and rest. In bed, when one puts one's hands over one's head the arms lie inertly on the pillow. They have position, not posture, because they are not muscularly active but at rest.

Pain may arise from the position imposed on a part if the position is long or frequently maintained. For example, there may be pain in the region of the internal lateral ligament of the knee without any other clinical manifestations. Such pain I have found is associated with the frequent curling of the toes around the legs of a chair from within out. The thigh and toes are supported; the heel is free, and the weight of the leg draws it into extreme external rotation and abduction. The chief sustaining structure is the internal lateral ligament of the knee. How frequently or how long this position must be maintained before pain develops I am unable to say. However, once such pain has occurred the person may be free from it a good share of the time as he moves around, only to have it appear a few minutes after he has seated himself and assumed his favorite position. The pain may be quickly relieved by placing the feet forward, or wrapping them around the chair leg the other way.

Discomfort may come while a person is lying in bed on his face. I have observed the development of pain in the shoulders severe enough to wake one up when the forearms are placed under the forehead or above the head while sleeping. The pain occurs in the anterior part of the shoulder in the region of the bicipital groove. It is almost instantaneously relieved by placing the hands under the thighs.

A third form of positional pain arises when a person is in the prone position and one thigh is drawn up into abduction. The pelvis is raised on that side and the trunk tends to be flat; the result is a localized painful strain on the elevated side of the lumbosacral junction. This is quickly relieved by straightening the thigh.

It would seem, therefore, that the pain arises from a chronic strain of ligaments or tendons not ordinarily subjected to long-continued strains.

These brief observations may seem of little moment, but such pain is baffling to one who has been taught to seek only after the hard things. It is annoying to the patient and hard on the physician's reputation if he does not find the cause.

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THE TELESCOPING V OSTEOTOMY

A GENERAL METHOD FOR CORRECTING ANGULAR AND ROTATIONAL DISALINEMENTS

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Stable impingement of fracture fragments often occurs spontaneously. Maintenance of position is seldom a problem, and union is usually prompt. This principle of stable apposition has been generally applied in the treatment of fractures. In most cases the surgeon strives for such apposition in performing osteotomy.

The pointed telescoping type of osteotomy is not new, but I feel that the principle of inherent stability deserves a more general application through the simple method of this type of osteotomy than is often observed. While most surgeons have utilized the principle, the method receives scant attention (Steindler [1]; Campbell [2]). When the principle is properly applied, slight but precise corrections are easily maintained, and great modification of alinement may be attained without resort to a complicated procedure or to metallic fixation.

Up to late in the nineteenth century osteoclasis was the only safe means of correcting deformities of the long bones. During the twentieth century roentgenograms and open osteotomy have provided such an opportunity for precise planning and meticulous execution that the restricted field of osteoclasis has been replaced by the virtually unlimited field of osteotomy. Bony deformities of all ages have been the seat of almost every conceivable type, pattern and complexity of osteotomy.

TYPES OF OSTEOTOMY

The basic types of osteotomy follow the types of fractures of the long bones. Thus, the osteotomy may be transverse, oblique, curvilinear, longitudinal or stepped. The ends of the cut bone may be smooth or irregularly pointed, comminuted or splintered.

A wedge effect is obtained with a transverse osteotomy at the site of angulation if impingement of the outer cortices results in a hinge action with opening of the concavity of the deformity on straightening the bone. This also slightly lengthens the bone. Apposition is consequently limited, the position is not secure and the method is applicable to relatively minor deformities. The fragments tend to readjust themselves to secure more stable apposition, with loss of correction, or sometimes slip entirely, with overriding. This situation was so obvious that the origin of cuneiform osteotomy probably goes back at least to the time of Macewen.[3]

Wedge or cuneiform osteotomy may be readily adapted to the large majority of angular deformities of the long bones. The shape, size and location of the wedge can be anticipated with geometric accuracy by means of roentgenograms. Occa-

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This article is based on a preliminary report read at the meeting of the Western Orthopedic Association, Seattle, July 30, 1937.

1. Steindler, A.: Orthopedic Operations, Springfield Ill., Charles C Thomas, Publisher, 1940.

2. Campbell, W. C.: Operative Orthopedics, St. Louis, C. V. Mosby Company, 1939.

3. Macewen, W.: Clinical Lecture on Antiseptic Osteotomy, Lancet **1**:449, 1878; cited by Steindler.[1]

sionally the site of the wedge is slow to unite. If the wedge is cleanly removed, two relatively plane surfaces are left, leaving a problem of maintenance that has not always been solved, especially in the adult. This has led to utilization of various means of internal fixation, and more recently, as in Pauwels' [4] reinclination operation (Schanz operation), to the use of transfixation spikes extending out of the wound for fixation in the plaster cast.

The easier problem of maintenance encountered when fracture fragments present relatively transverse but irregular surfaces has naturally led to stimulation of that advantage in osteotomy. This is seen to an advanced degree in the longitudinal or splintering osteotomy of Haas.[5]

The difficulties presented by mature bones with a tendency to break, splinter and displace have led to the application of suitable technics. The curvilinear, stepped and flanged osteotomies, with or without removal of a wedge and sometimes with the use of multiple drill holes to avoid splintering, have had their widest application at the knee and the trochanteric region of the hip. These types have been variously employed, as to previous technic, by different men for many years.

The problem of adequate correction and maintenance of good apposition has been further met by the development of the incomplete osteotomy, the surgeon trusting to an adequate hinge effect on the outer side of the angulation. This principle is limited in its application to the young patient and to sites where the cortex is sufficiently thin to bend rather than break.

A method of osteotomy more generally applicable is that of the oblique or pointed type, the surgeon electing to shape the bone fragments so that one end may impinge onto or into the other.

The soundness of this principle has been well tested. From time immemorial those who set broken bones have endeavored to fix one irregularity into the other. This principle has been invoked in bone grafting, as witness the intramedullary peg, fishtail and combined intramedullary and inlay grafts. It has been advocated for securing maintenance without internal fixation in the open reduction of fractures. It has often been spontaneously at work with a fracture, at osteoclasis and in incomplete fracture or osteotomy. It has been purposely utilized in the various types of subtrochanteric osteotomy at the hip, as recorded by Schumm [6] (though with transfixion pins) and others.

The technic of Klapp,[7] applied at a level where the shaft is of uniform diameter and the bone is wholly cortical, utilizes this principle, though it is difficult to form a socket for the pointed fragment without undue splintering.

One method of correcting hammer toe deformity includes resection of the joint and insertion of the pointed shaft of the proximal phalanx into the larger base of the middle phalanx (Young [8]; Higgs [9]).

BONE REPAIR

While there is little precise information as to the biophysical mechanism of bone repair, the anatomic factors underlying it are well understood. Given a frac-

4. Pauwel, F.: Pauwel's Subtrochanteric Wedge Osteotomy in Treatment of Pseudarthrosis of Neck: Case (J. H. Sickmann), Deutsche Ztschr. f. Chir. **229**:336-342, 1930.

5. Haas, S. L.: Longitudinal Osteotomy, J. A. M. A. **92**:1656-1658 (May 18) 1929.

6. Schumm, H. C.: The Schanz Osteotomy for Fractures of the Neck of the Femur, J. Bone & Joint Surg. **19**:955-963, 1937.

7. Klapp, R.: Demonstrationen aus der praktischen Chirurgie . . . Anspitzende Osteotomie, Arch. f. klin. Chir. **177**:688-694, 1933.

8. Young, C. S.: Operation for Correction of Hammer-Toe and Claw-Toe, J. Bone & Joint Surg. **20**:715-719, 1938.

9. Higgs, S. L.: "Hammer-Toe," M. Press **131**:473-475, 1931.

ture of bone or an osteotomy with largely viable fragments lying in close apposition to one another and surrounded by a periosteal envelope, and maintained there, prompt bony union is almost inevitable.

Since an osteotomy is an elective procedure, the surgeon may well require that it conform to these basic principles.

THE TELESCOPING V OSTEOTOMY

The method of the telescoping pointed or V osteotomy is applicable to the correction of deformities and conditions necessitating realinement of a bone at a level where the bone is conoidal as seen in longitudinal section. The diaphysial-

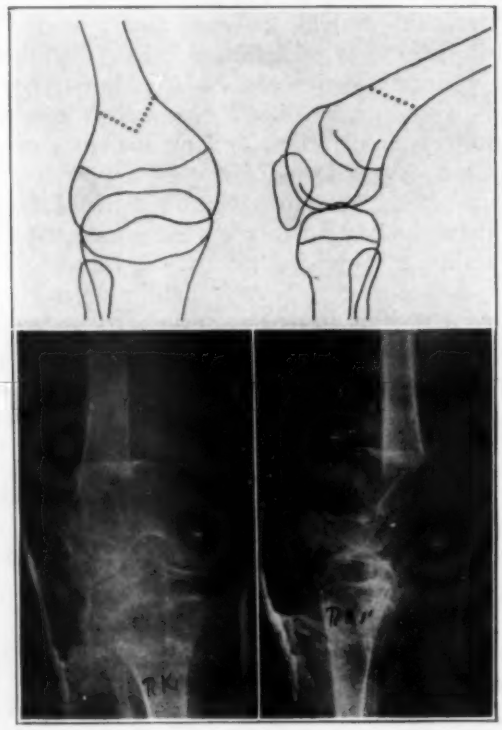

Fig. 1.—The tracings show the valgus type flexed knee of an externally rotated flail leg. The dotted line indicates the proposed osteotomy.

The roentgenograms show the pointed fragment of the shaft telescoped into the metaphysis, correcting the disalinements. Unless epiphysial fusion is present or imminent, deformity from further growth may occur.

metaphysial junction and the metaphysial region of most of the long bones provide this basic requirement. Some diaphysial malunions are also suitable.

The bone is exposed subperiosteally for a short distance on the outer side of the angulation. A V osteotomy is performed, the apex pointing toward the metaphysis and the plane of the osteotomy passing somewhat obliquely away from the metaphysis. In the young person the bone may be incompletely cut, the inner cortex acting as a hinge (fig. 1). Where the cortex on the inner side of the osteotomy is thick, it is better to section the bone completely, to avoid a spiral fracture, or leave but a small section to be broken when the deformity is corrected (fig. 5).

The pointed side of the osteotomy is smaller and more cortical in structure than the metaphysial receptor side. With slight beveling, the pointed fragment telescopes within the larger. Marked degrees of deformity require, as does rather dense cancellous bone, that the receptor side be somewhat excavated to receive the V point deeply enough to make the telescoping adequate for correction and positive fixation (fig. 2). If the beveling is insufficient, relatively small wedges require removal to avoid impingement of the cortices and consequent loss of apposition and locking. This is important in correcting extreme deformities, when occasionally shortening may be necessary to avoid undue tension on major nerves

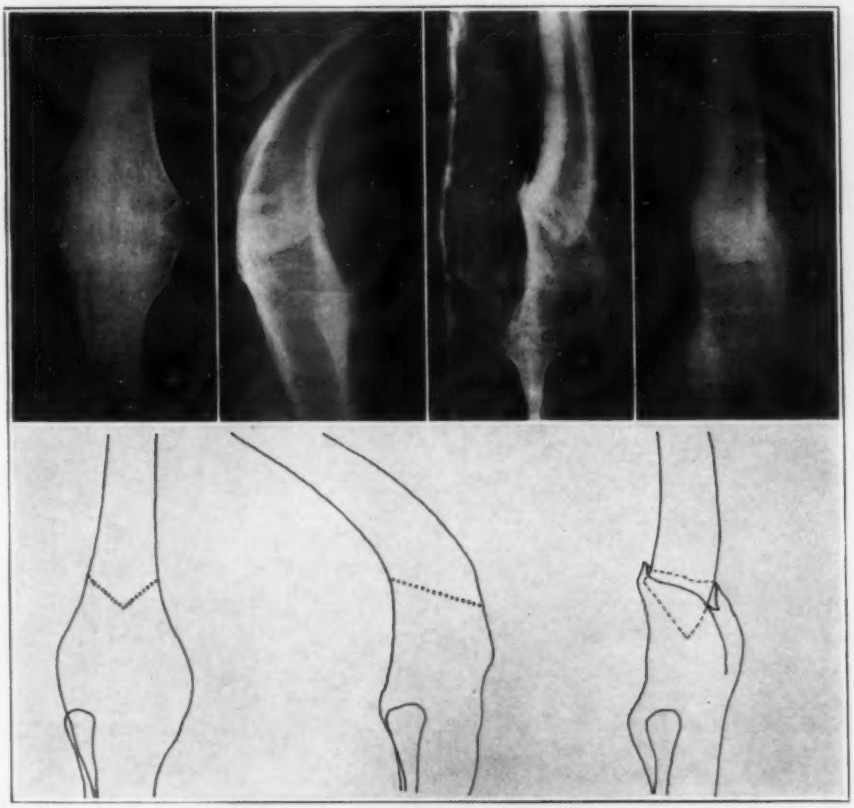

Fig. 2.—The two roentgenograms to the left show an adult surgically fused postparalytic knee that, through growth disturbance, had undergone flexion and external rotation. The two postoperative lateral views were taken one day and forty-three days after correction. The tracings indicate the proposed osteotomy by dotted lines. The telescoped end is shown by a broken line.

and blood vessels. Usually, as measured on the inside of the angular deformity, little or no actual shortening occurs.

Thirty years ago, Osgood [10] resected a quadrilateral wedge with the geometric accuracy afforded by roentgen studies and a cardboard model (fig. 3). He shaped the larger distal fragment so that it would retain the smaller when in the corrected position. He noted especially the precision of the correction, its secure maintenance and the early firmness of union.

10. Osgood, R. B.: A Method of Osteotomy of the Lower End of the Femur in Cases of Permanent Flexion of the Knee Joint, Am. J. Orthop. Surg. **11**:336-346, 1913.

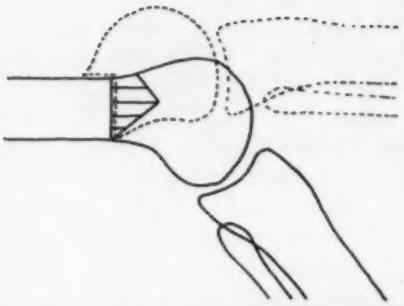

Fig. 3.—Diagram redrawn from Osgood.[10] The permanently flexed knee is shown by solid lines. The shaded area is the quadrilateral wedge, which when removed permits correction as indicated by the broken outline.

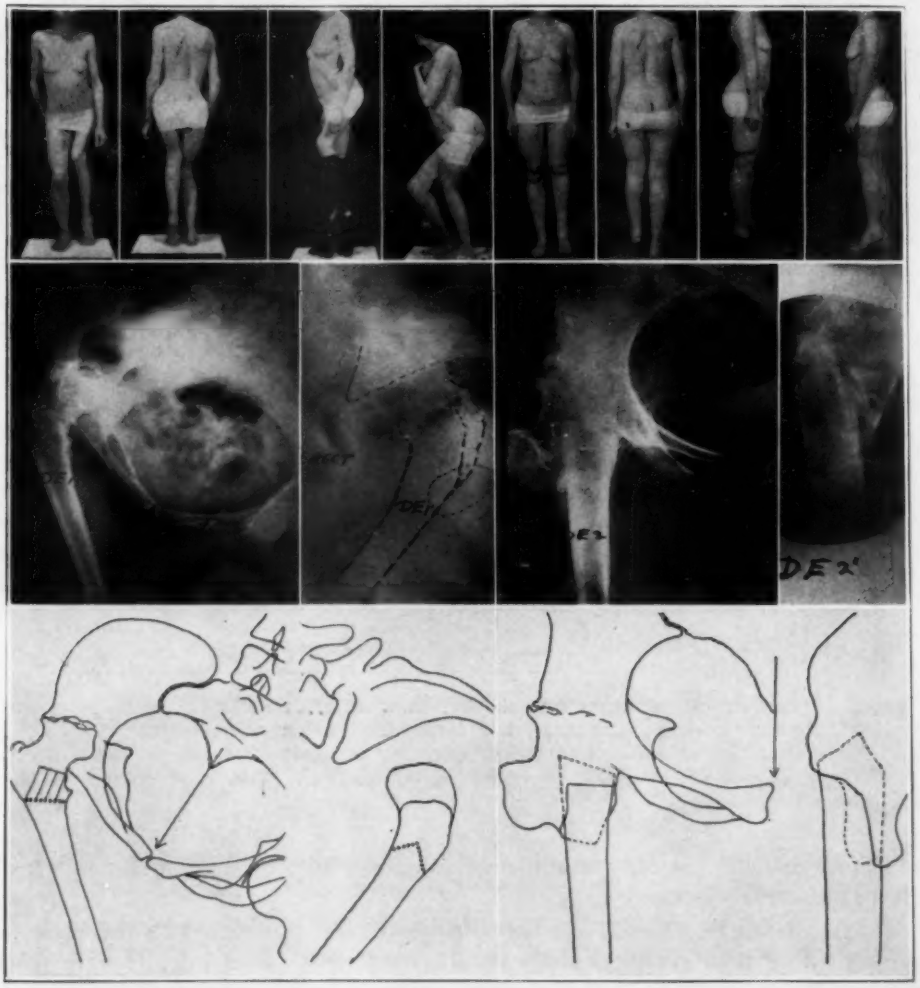

Fig. 4.—Old tuberculous hip disease with severe flexion–adduction–internal rotation deformity.
Photographs: left, preoperative; right, five years postoperative.
Roentgenograms: left, preoperative; right, three months postoperative, taken when the patient began weight-bearing in a short spica.
Tracings: left, preoperative. The pointed osteotomy site is shown by a dotted line; the shaded area represents the anterior quadrilateral wedge. Right, postoperative. The broken line indicates the telescoped portion of the distal fragment.

While telescoping of the pointed end of the V osteotomy usually makes resection of cortical bone unnecessary, extreme deformity with scarring of soft tissue may be treated by quadrilateral resection and telescoping to secure stability in all directions.

Such application of the principle was made in the case of a 37 year old woman who had suffered from tuberculosis of the hip from the age of 3, with development of a severe flexion–adduction–internal rotation deformity (fig. 4). A quadrilateral

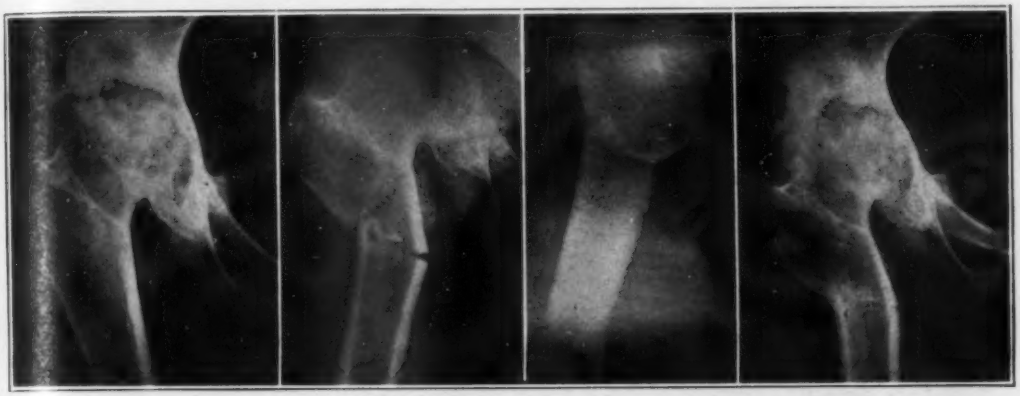

Fig. 5.—Adducted, probably tuberculous hip of a 31 year old white man. Roentgenograms from left to right: (1) preoperative; (2) postoperative, taken with the hip in a cast (operation March 2, 1937); (3) lateral view of March 9, 1937, with site of osteotomy scarcely discernible; (4) anteroposterior view three months after operation. The vertical line of the view is parallel to the midline of the body.

Fig. 6.—Nonunion of a fractured femoral neck with a viable head. The views from left to right are preoperative and two and one-half months postoperative. The point of the V cut bone is seen telescoped within the intertrochanteric bone. The head is in valgus position. The greater trochanter is below the acetabular margin.

wedge was removed anteriorly and the posterior cortex was bent back to overlap greatly the distal fragment. The hip joint was bone grafted at the same time with the anterior portion of the ilium. Union was prompt, although a tuberculous abscess was encountered.

Whether for slight or marked correction, this procedure closely simulates the impacted (or "telescoping") metaphysial fracture in which apposition and

union are often so firm and prompt as to discourage the surgeon from trying to modify the position a week or so later.

Rotational realinement is obtained by rotating the pointed fragment into line and forcing it into the receptor fragment, a socket having been gouged out if the cancellous bone is too dense or the surface is so large as to prevent sufficient telescoping. The deformities illustrated in figures 1, 2, 4, 6 and 7 presented rotational as well as angular elements.

The shortening as measured on the concavity of the deformity arising from the telescoping is identical with that of the typical cuneiform osteotomy, though occasionally there is slight lengthening as the inner side opens up when the telescoping fragments are firmly seated. Figure 5 illustrates slight lengthening on the inner side. This adducted tuberculous hip was bone grafted at the time of osteotomy. Stable union was remarkably rapid even for this favorable site.

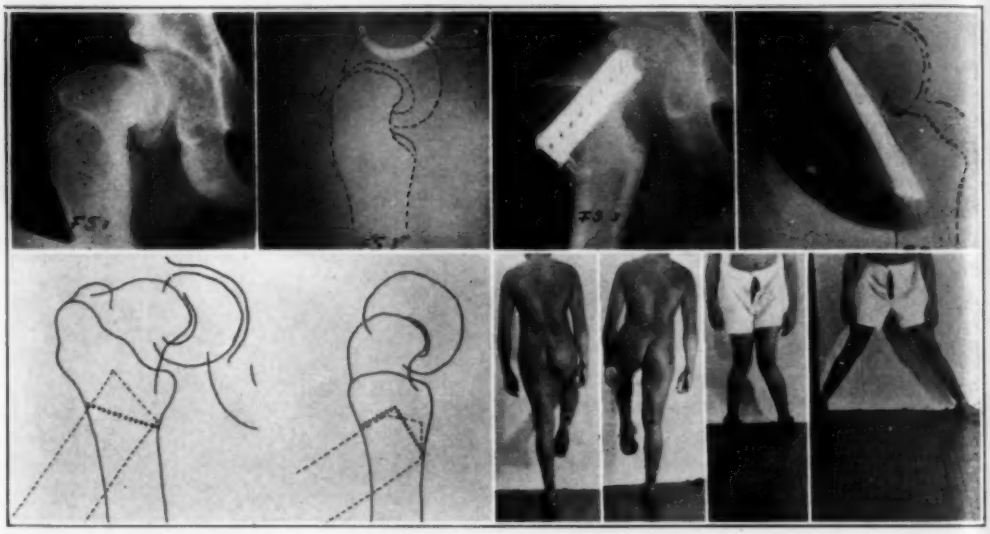

Fig. 7.—Slipped femoral epiphysis in a Negro boy of 14.
Roentgenograms: left, preoperative; right, four months postoperative.
Tracings: dots indicate the proposed osteotomy; broken lines, the desired position.
Photographs: patient one and one-half years later.

It should be noted that even with marked deformities there is little or no shortening as measured by the length of the bone on the concavity or inner angle of the deformity. It is axiomatic that the greater the angular deformity the greater the gain in functional length on correction of the deformity

More difficult to correct and maintain in correction is a femoral head that has become displaced (rotated) because of nonunion of a fractured femoral neck or because of slipping of a femoral epiphysis. In both instances the head is rotated backward and downward resulting in coxa vara and external rotation.

Figure 6 presents nonunion of a fractured femoral neck with varus deformity and external rotation. Note the obliquity of the fracture plane to the weight-bearing line. After osteotomy a position of complete valgus is obtained, the marked external rotation is corrected and the weight-bearing line meets the fracture plane at nearly a right angle. The apex of the V osteotomy was made posterolaterally, the shaft freed and rotated forward 60 degrees and forced posteromedially into the intertrochanteric region so as to cause adduction and extension of the proximal

fragment, the distal shaft remaining in neutral position. A plaster cast was used for fixation. Union at the site of the osteotomy and at that of the fracture of the femoral neck was prompt.

A marked coxa vara due to slipping of the femoral epiphysis presents a similar problem.

Figure 7 shows a precisely similar correction save for a nail driven across the epiphysial line. A wire loop was used to connect the nail and the distal fragment from osteotomy since 60 degree antiversion angulation was obtained and the operator's confidence in the procedure was not equal to the occasion. It is not now believed that the wiring was necessary. The photographs show the abduction and internal rotation gained. There is no limp.

SUMMARY

A method is described for performing osteotomy to correct deformities in which the bone is conoidal in longitudinal section. By a pointed or V osteotomy the smaller fragment may be partially telescoped into the larger to obtain any desired wedge effect or rotational correction. Because of the firm apposition of the partially telescoped living bone fragments enveloped by periosteum, stability is marked and union prompt. No special instruments are required. Plaster casts are used for maintenance. This method of performing osteotomy has been used in diverse situations with good results. While rather marked deformities are shown, the method is no less simple and secure with the mild ones.

Major Francis McKeever, Medical Corps, Army of the United States, gave me permission to use the case shown in figure 1.

2007 Wilshire Boulevard.

PARATROOPER FRACTURE

CAPTAIN WILLIAM J. TOBIN
MEDICAL CORPS, ARMY OF THE UNITED STATES

Every now and then there appears in the literature a name associated with a definite type of fracture because of the latter's frequent occurrence in a certain type of injury. Among these are the "crank" fracture of the lower end of the forearm due to the "back kick" of the crank, the "bumper" fracture of the upper end of the tibia and the "dashboard" fracture of the acetabulum.

In two years' observation of the fractures occurring among the parachute jumpers or "paratroopers" in training at Fort Benning, Ga., it has been noted that a substantial number of the jumpers sustain fracture of the posterior articular margin or "posterior lip" of the tibia (fig. 1). Fracture of this type occurring alone constitutes about 12 per cent of the total number of fractures (272). At least another 4 per cent consist of fracture of the posterior lip of the tibia associated with fracture of the internal or the external malleolus. At times the fracture of the posterior lip of the tibia occurs with bimalleolar fracture—forming the trimalleolar fracture of the ankle joint (fig. 2).

In civilian practice it is believed that fracture of the posterior lip of the tibia is relatively uncommon. The usual history in civilian life is that the patient was "tripped" by the heel of the shoe being caught on a step or on a curbing with the foot in equinus position and the weight of the body thrust forward. As the average civilian shoe is a "low quarter" shoe, there is little or no support to the posterior structures of the ankle joint, and when this fracture occurs, open reduction is sometimes necessary to bring about reapproximation of the fragments. While the fracture occurs much more frequently in paratroopers than in civilians, it is not severe.

There has been no case in the series studied that required an open reduction. Undoubtedly, the high tight-fitting boot worn by the jumpers explains this. The astragulus is not pushed backward to any appreciable degree, and consequently the integrity of the posterior ligamentous structures, while stretched and undoubtedly partially torn, are not completely separated. Naturally, if the causative force is sufficiently great, as in a few cases, there does occur a posterior dislocation of the ankle joint.

Another interesting observation has been that the jumpers often "reach for the ground" when they are about 20 feet (6 meters) from it. As a result, the foot is in plantar flexion. It is a popular misconception that the parachute jumper descends in a vertical plane and contacts the ground upright. This, as a rule, is not the case. Such a landing could occur only if there were no wind currents.

Oscillation of the parachute is the biggest individual factor in the production of injuries, including fractures, among the jumpers. It is this oscillation that causes the jumper to contact the ground sideways, forward or backward.

The force of the impact with the ground can be compared to that of a man running and then jumping from a platform 12 feet (3.5 meters) high. There is that forward motion that is not appreciated by many persons. The men are

instructed to land on the balls of their feet and then go into a forward roll to absorb much of this particular shock. Metatarsal fractures constitute only about 5 per cent of the total number of fractures. As the actual percentages of the various types of fractures have been described previously by me,[1] no attempt will be made to elaborate on them here.

It may be mentioned that in frequency the most common individual fracture is that of the external malleolus—due to the same mechanism as that of the com-

Fig. 1.—Typical fracture of the posterior lip of the tibia. This usually occurs alone, and there is no appreciable separation of the fragments.

mon sprain of the ankle, i. e., adduction and inversion of the foot. Fractures of this type constitute 23 per cent of all the fractures seen among jumpers, with the ankle in a neutral position.

1. Tobin, W. J.; Cohen, L. J., and Vandover, J. T.: Parachute Injuries, J. A. M. A. **117:** 1318-1321 (Oct. 18) 1941. Tobin, W. J.; Ciccone, R.; Vandover, J. T., and Wohl, C. W.: Parachute Injuries, Army M. Bull., April 1943.

From the anatomic point of view, the superior surface of the astragulus and the inferior articular surface of the tibia are parallel and perpendicular to the long axis of the tibia. With the foot in plantar flexion, the posterosuperior articular surface of the astragulus, which presents this structure's most narrow transverse diameter, is in contact with the articular surface of the tibia. In this position it is less firmly locked than in dorsiflexion. Normal plantar flexion is 145 degrees, but this is a variable figure. The posterior articular ligament is relaxed in plantar flexion—hence little or no support is presented to the force

Fig. 2.—Fracture of the posterior lip of the tibia associated with a fracture of the internal malleolus and an oblique fracture of the lower part of the shaft of the fibula.

transmitted upward through the long axis of the foot through the astragulus to the lower end of the tibia. The result is a "shearing" off of the posterior articular surface of the tibia, the so-called posterior lip or third malleolus.

As a routine procedure—whether the fracture of the posterior lip occurred alone or in junction with a fracture of the external malleolus—treatment consisted in immobilizing the joint for an average of four weeks in a skin-tight plaster cast with a walking iron attached. The incomplete fractures required less time than those in which separation of the fragments had taken place.

In cases of trimalleolar fracture, weight bearing was not instituted early, in fear of a separation of the malleoli. Fracture of this type has been considered sufficiently severe to justify recommending the jumper for a permanent nonjump status.

Jumpers with uncomplicated fracture of the posterior lip were allowed to return to jump training after an adequate period—seldom under three months.

In conclusion, it is felt that fracture of the posterior lip of the tibia is occurring frequently enough among the paratroopers to justify the introduction of the phrase "paratrooper fracture," as it is believed that in no other occupation does this particular fracture occur as frequently.

The photographs are reproduced with the permission of the 161st Signal Photographic Company, Signal Corps, Army of the United States.

TORSION OF THE ACHILLES TENDON: ITS SURGICAL SIGNIFICANCE

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GREENVILLE, S. C.

Lengthening the heel cord is the commonest single operative procedure in the repertoire of most orthopedic surgeons, and the reporting of any simplification of the technic seems justified, particularly if it brings to light an interesting embryologic phenomenon which explains the internal arrangement of the fibers of that structure, not generally appreciated. Before I developed my special but simple technic of subcutaneous tenotomy, I had abandoned that procedure because of frequent inability to get the severed tendon elements to slide apart, regardless of the near completeness of the alternate transverse cuts, and had employed an open tenoplastic technic, converting what should be a relatively simple operation into a much more formidable one.

The satisfaction that has long accompanied this lengthening procedure, together with the continual urging of my friends that I publish a description of the procedure, has finally prompted me to finish a task started many years ago, when it was submitted as a successful thesis. The paper was even read at one of the national meetings but, partly for the reason that the embryologic phase had not been thoroughly worked out and for various other reasons, it never appeared in print. A particularly favorable opportunity for publication has presented itself and I am most happy to have included in this volume a contribution which I feel has considerable value and which I believe has been my most important original contribution. I present it as a token of sincere appreciation for the opportunity in orthopedic surgery made possible for me by the one to whom this volume is dedicated.

The lengthening of the achilles tendon was really the first modern orthopedic operation to be performed and has continued to be the most frequent single procedure employed in this branch of surgery. It is relatively simple, but any one who has done it many times has been impressed by the difficulty frequently encountered before the partially severed tendon sections slide apart, and by how much of the tendon has to be severed before the lengthening is accomplished. Not infrequently the operator fears that he has completely severed the tendon at the proximal or the distal transverse cut and is far from being satisfied with a job that, with knowledge of the internal structure of the tendon, is so certain. Even when the tendon is generously exposed it is difficult to do a neat job without this information. The technic necessitating three transverse cuts is far from satisfactory, and although the desired results are finally accomplished, there is no comparison between the two procedures after one has done the lengthening operation a few times in the manner about to be described.

Any suggestion that can facilitate the performance of such an important and frequent operation I feel will be welcome, and the only apology that I believe to be in order at this time is that relative to the delay in publishing the technic after employing it for so many years myself.

In brief, the explanation of the difficulty encountered in lengthening the heel cord by simple subcutaneous tenotomies lies in the fact that there is approximately a 90 degree twist of the structure on its own axis within the surgical field and

that when even two thirds of the medial fibers have been severed at one level and two thirds of the lateral fibers at another level, enough fibers miss being cut to cause the tendon to "hang." An ordinary twisted Manila rope would behave in the same way if cut partially at different levels and cognizance were not taken of the twist to make appropriate cuts.

When this abnormality in the internal structure of the achilles tendon is appreciated (at least in comparison of this with other tendons) and the transverse partial tenotomies are made with it in mind, no difficulty is experienced in lengthening a tendon previously not operated on. If the anterior two thirds of the heel cord is severed a convenient distance above its insertion into the calcaneal tuberosity,

Fig. 1.—Photograph of the achilles tendons showing the torsion.

and the medial two thirds is severed 2 or 3 inches (5 or 7.5 cm.) above this point in an adult, no difficulty will be encountered in elongating the tendon by applying moderate dorsiflexion force to the forefoot in an uncomplicated equinus deformity. The exact technic employed calls for starting the proximal transverse tenotomy on the medial side of the tendon, after the anterior two thirds has been cut about 2 inches distally, continuing with it laterally until the tendon sections are felt to slide apart while the previously mentioned moderate dorsiflexion force is being applied to the forefoot.

It is suggested that before this procedure is done subcutaneously it be done several times with the tendon exposed, until the mechanics of the situation is thoroughly appreciated and confidence established. Later it might be interesting as an occasional demonstration to do the subcutaneous procedure and then expose

the lengthened tendon to prove the efficacy of the operation. Ordinarily, of course, nothing is done but the properly located transverse tenotomies.

This torsion of the achilles tendon is not described in any modern anatomic textbook, although the artists in drawing many of the illustrations have frequently depicted this phenomenon accurately. The only discussion of this condition I have been able to discover appeared almost half a century ago—that of Parsons, who described the heel cord in the Canadian beaver. He does not say definitely but implies that the twist that he had noted in this industrious animal must be present in man.

I have dissected the commoner domestic mammals and found this same torsion to be present in each, and I assume that it must be present in all animals in which there occurs the peculiar rotation of the posterior tarsus on which this morphologic character depends.

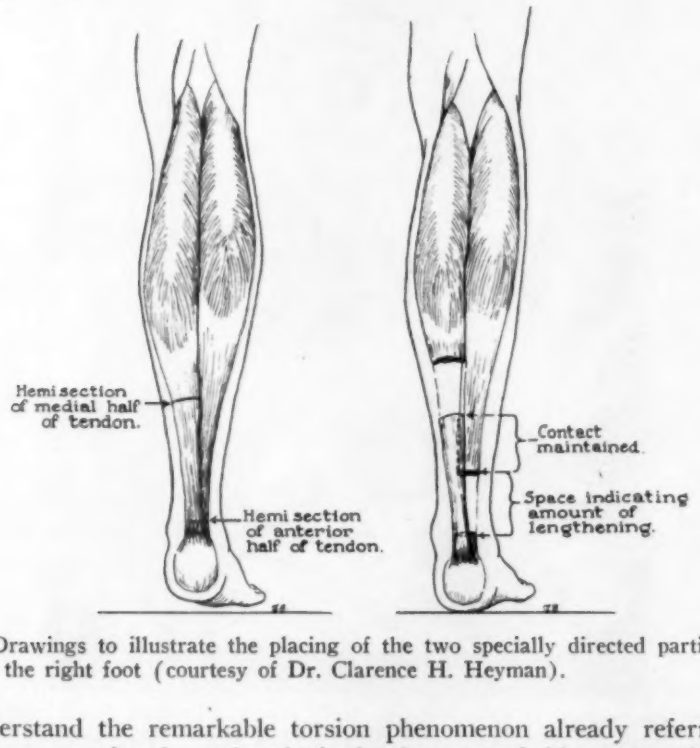
Hemisection of medial half of tendon.
Hemisection of anterior half of tendon.
Contact maintained.
Space indicating amount of lengthening.

Fig. 2.—Drawings to illustrate the placing of the two specially directed partial transverse cuts, both of the right foot (courtesy of Dr. Clarence H. Heyman).

To understand the remarkable torsion phenomenon already referred to, one must briefly summarize the embryologic development of this apparently uncomplicated region. No one has yet been able to demonstrate accurately the very early stages by which the undifferentiated flipper-like limb bud develops into the structural formation of the ankle. The transition apparently occurs so quickly that sections of the limb buds showing this transition stage have not yet been obtained, and so the following explanation must be based largely on theory but, none the less, theory depending on anatomically recognized facts.

To explain successfully what one finds in the internal structure of the heel cord, one must assume that the anlages of the os calcis and the astragalus are the os tibiale and the os fibulare, respectively, located at the ends originally of their corresponding bones. As the side by side relationship of these two anlages changes to an under-over position, the tendinous portions of the muscular anlages of the inner and outer heads of the gastrocnemius muscle inserted into the anlages at the

distal ends of the tibia and the fibula rotate necessarily through an angle of 90 degrees while the corresponding 90 degrees' angulation of the ankle is being developed. Incidentally, it might be interesting to recall here that one derivation of the word "angle" is from this joint, which of course existed ages before man had any sort of language. The tendon of the outer head of the gastrocnemius muscle being inserted into the anlage of the os fibulare is carried at its insertion forward and above the insertion of the outer head into the tuberosity of the os calcis. The soleus muscle tendon continues between these two tendons until they all fuse into the tuberosity, losing its identity in man with the short flexor muscle of the toes, which apparently persists in all lower mammals, certainly the domestic animals which I have dissected personally.

As the tendons change their relationship from the side by side position to an anterior-posterior position, the tendon of the outer head becomes fused with the tendon of the inner head and loses its attachment to the os fibulare, now the astragalus, the soleus muscle tendon, as stated, evidently fusing between them, a fact which becomes apparent in a macerated specimen.

When the anterior portion of the heel cord is cut near its insertion into the os calcis, the fibers that remain uncut are the fibers from the inner head and are located on the medial portion of the large conjoined tendon proximally. Therefore when the medial portion of the structure is severed proximally, all fibers are severed and the sections slide apart with a minimum of effort.

While I am unable to follow the same analogy through, I feel sure that the crossing of the tendons of the peroneus longus muscle and the posterior tibial muscle in the forefoot is associated with this posterior tarsal rotation of the os calcis and the astragalus. To substantiate this further, one may recall the anatomic position of the upper extremity when the forearm is in full supination; i. e., the first digit is lateral, while in the foot the first digit is medial. The whole explanation is out of the field of the orthopedic surgeon and, it is anticipated, will some day be worked out accurately by the embryologist. It is hoped that the reader has not been too confused by this rather complicated discussion, which was deemed to be of sufficient interest to be included in this primarily clinical paper.

Regardless of the correctness of the explanation, the subcutaneous tenotomy using only the two specially directed partial transverse cuts permits the two tendon sections to be slid apart with sufficient ease to simplify the lengthening of the achilles tendon and is heartily recommended for routine use in this frequent orthopedic procedure.

206 East North Street.

REHABILITATION IN WARTIME BRITAIN

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During a recent tour of duty as surgeon in chief of the American Hospital in Britain (February to August 1942) I became interested in the problem of rehabilitation as faced by the Armed Forces of Great Britain. In the Churchill Hospital at Oxford my associates and I were de facto a reconstruction unit placed at the disposal of all branches of the services. A great many of the military patients were there as a result of accidents in the course of training and of accidents in transport. Others came from far off Libya, while there were even a few left over from Dunkirk. Thus there was a mixture of recent to moderately recent injuries, including both simple and compound fractures, together with older problems of nonunion and malunion, often associated with osteomyelitis, and always in these older problems there was the element of impaired function with its threat of permanent disability of a high degree. The sources of the most severe injuries were blasts and motorcycle accidents. In the former a man was often hurled through the air to receive multiple fractures and other injuries on encountering solid resistance. The same type of injury resulted when motorcycles driven at a high rate of speed skidded or otherwise went out of control on the wet winding narrow roads of England. These men sustained severe shock in addition to multiple fractures, and there were not infrequently internal injuries. In consequence, the primary problem of treatment was often that of preserving life, and the final treatment of the fractures aside from temporary splinting had to be postponed. By the time such patients were admitted to Churchill Hospital, four to six weeks had frequently elapsed. All in all, this group offered a serious challenge to our reconstruction group. Exactly similar problems were encountered in the various British military hospitals. Similar problems were sometimes found in civilians who were injured by air raids.

One of the primary lessons which has to be assimilated by one who turns from civilian to military surgical problems is that the primary purpose of an army is to fight battles and win the war. In England the purpose of the Royal Army Medical Corps is to restore men to front line duty, and if there is any man for whom that cannot be done, to discharge such a man from the Army and thus disencumber themselves of useless "debris." This greatly simplifies the problems of the Army and Navy medical services.

In practice the maximum period of disability within the Army has been arbitrarily set at one year. Inspection boards are created in each hospital region, and each man is examined by one or two medical officers at about three and seven months after injury and the findings reported to the central board together with the recommendations of the examiners. If at the three month period it is apparent that the injured man will not be able to regain usefulness to the Army within the year, he is at once discharged. Most of the patients are retained until the seven month examination, when there is a further determination of fitness, while a few may not have final judgment passed until the twelve month period is about completed. No man may be retained in the Army if he is unable to return to duty at the year's end. The Royal Navy, on the other hand, does not have any arbitrary

period for discharge but tends to keep the men on its list as long as active treatment is indicated or until the maximum of restoration has been accomplished.

Discharge from the Army for reason of continued disability did not mean that the man would be neglected. Responsibility merely passed from the Army to the Ministry of Pensions, which was then charged with the man's further treatment and with his ultimate education toward usefulness in civilian life on the basis of impairment. At Churchill Hospital this change of control usually permitted the patient to remain under treatment, with the sole change one of ultimate responsibility. Naturally, persons who had had amputations tended to become early charges of the Ministry of Pensions and were all concentrated at Roehampton under Mr. Perkins. Civilians who sustained disability became charges of the Ministry of Labor, whose duty it was to restore them to industry by training at various regional schools.

Primary rehabilitation, of course, was begun in the hospital. We were furnished by the British Ministry of Health with completely equipped departments of physical and occupational therapy. The personnel was British, and the members were efficient and exceptionally well trained. There were four physical therapeutists and a well equipped gymnasium (which was designed to be part of a receiving unit in case of emergency). The equipment consisted of various heat-producing units, including short wave machines, paraffin baths, wrist and forearm exercisers and other equipment standard in the better American hospitals. Occupational therapy was divided into carpentry work, which was directed by a practical joiner secured from Oxford, and knitting and weaving. The British soldier has a passion for embroidering his regimental coat of arms on anything from a pillow to a blanket. This is begun before he is able to sit up. Others knit and weave rugs. One of the great events of Churchill Hospital was the composition of a quilt bearing the insignia of every military unit represented at the hospital. The quilt was sent to President Roosevelt in honor of the American origin of this hospital. All of these activities and many others, begun early, diverted the patient's mind from his own problems and kept him busy. When weight bearing was begun, the patients began to wait on themselves and to walk outdoors where they worked in vegetable gardens, of which there was one for each ward. At this stage of convalescence they went to a central dining room for their meals.

At this point, more purposeful work was begun by "P. T. sergeants" (instructors in physical training), who put these men who were in the early stages of convalescence through limited drills designed to build up endurance and to combat habitual limping. Such patients were sent shortly to convalescent homes, which were manor houses taken over by the Knights of St. John of the British Red Cross. There, physical therapy and drills were continued while, at the same time, there was increased opportunity for outdoor activities, such as golf on improvised courses and bowling on the green. It should be noted that many of these patients were activated in casts with thick rubber blocks fastened to the soles. The problem of the habitual limp had concerned me in civilian practice only in connection with certain patients whom I had considered neurotic. In mass rehabilitation it has been discovered that it is a factor of major importance which must be met by early emphasis on the correct method of normal walking. The "P. T. sergeants" are equipped to cajole, entice or warn men to use both the heel and the toe.

As soon as healing is completed, the soldier is discharged to a rehabilitation camp, where his activity is rapidly increased until he is restored to full time duty.

All of our patients were sent to Westbury. Unfortunately, the soldiers were allowed only four weeks of such training, and we therefore tended to keep them under care in one of the convalescent homes until we were certain that four weeks of fairly strenuous activity would enable them to return to active duty. The result was prolongation of hospitalization with delay in final recovery. By far the better system was that of the Air Force, largely organized by Watson Jones. We were privileged to visit their center for the rehabilitation of noncommissioned officers at Hoylake near Liverpool. Patients are sent there as soon as it is felt that benefit will result from rehabilitation treatment. If their condition is such that they will be unable to resume flying, they are prepared, if possible, for ground duty. All who are sent there are judged able eventually to resume duty in one of these categories.

The Air Force occupied a peculiarly privileged place in England at the time of our visit. Of all the troops in England, they alone were in constant fighting contact with the enemy. Constant and successful efforts were made before and after the beginning of the war to build up a splendid morale peculiar to the service. Since their heroic work in the battle of Britain, nothing has been too good for them. They eat the best food obtainable in Britain and are granted more frequent short leaves than ground troops. They wear a distinctive uniform, and it is worn with a sense of pride. When they are injured, the problem of rehabilitation is both physical and psychologic. The most frequent injuries are burns and fractures, while the mental stress at the time of injury is frequently severe. Some of these boys had drifted in the water for from hours to days with severe injuries before being rescued. Others had received compound fractures from wounds received over France or Germany. In addition there were the usual training injuries of a large air force concentrated in a small island. In Oxford County alone there was one crash every twenty-four hours.

At Hoylake all the men were given the unusual privilege of sleeping until 7:30 in the morning. The program began at 10 a. m. and continued until 5 p. m., with an hour out for luncheon. Each man was assigned to a group, and the activities of the group changed every hour. These activities, for the most part, consisted of games which were fun to play and would cause the man to forget himself for the moment. Each group, of course, was graded according to the stage of recovery. Thus treatment of a man was begun as soon as he was able to wear a walking cast and consisted of squad drill, volley ball, sawing wood and physical therapy. Walking was made possible by fastening a rubber or felt square to the under heel of the cast. No walking irons were permitted, and I found that all medical officers were firmly of the opinion that walking irons contribute to the formation of a habitual limp, difficult to eradicate and persisting for a long time. Drill was in charge of physical training sergeants, who taught the men at the start to do heel and toe walking. Two separate hours a day were given to this activity.

Those who were capable of advanced training played tennis and volley ball, ran races and played a wonderful and strange combination of basket ball and rugby football which had been invented for boy scouts by the King. The field was about half the size of a football field. The ball could be advanced by passing, kicking or running. Goals were made by putting the ball in the basket. For purposes of safety, body tackling was eliminated in favor of touch tackling.

In addition to taking part in these and other games, each man spent a half hour with a physical therapeutist, during which baking and diathermy were given in addition to active local stretching exercises. But, of all that we saw, the most

unexpected sight was a dance hall wherein an array of limping men were gaily dancing to the tunes of records with very nice girls who came on schedule from Liverpool to carry out a fairly pleasant assignment. The morale officers made much of this activity and informed us that it was an important bridge for the advanced patients back into normal activity. One almost detected one's self limping hopefully. All in all, I was impressed by the fact that all of these activities were obviously fun to those participating. It did lead to a degree of activity which was almost unbelievable in a fairly short time. Constantly in the background were morale officers who were watchful for any evidence of psychologic breakdown. We were told that there was a very low but constant percentage of men who, for the latter reason, were eventually lost to the Air Force: the men who had lost their nerve.

The camp was an inspiring object to any orthopedic surgeon and should serve as an example to the Army of the United States. Up to August 1, the time of our departure, there had been no evidence of such interest. It was a time of hurried organization by the Surgeon General in England, who had first to secure and establish hospitals, organization and supplies, and this problem may have come up for study since. One could not help but reflect on the use to which a modified organization of this type could be put in peace times. Certainly rehabilitation centers organized along these lines would be a great boon to injured industrial workers, with places for the teaching of new skills to those unable to return to their former occupations. Until industrial commissions, employers and labor itself acquire a social point of view, such prospects are well nigh hopeless. Some day it will surely become recognized that the cheapest method of paying the cost of injuries will be along these lines. As long as penny pinching is the chief aim, the money of compensation will continue largely to occupy the minds of many injured employees.

Our experience in England revealed much the same class of problems that try us here in civilian practice. For instance, the problem of the femoral fracture is now fairly well solved by the means at hand if the surgeon has been adequately trained. The problem of the resulting stiffened knee is far from solved. Brigadier Bristow made the statement that not a single man treated for femoral fracture with displacement had been rehabilitated for service in the British Army one year after injury, the time for discharge of disabled soldiers. On the other hand, we saw many with 90 degrees of motion at the Air Force camp at Hoylake as testimony to the excellent results obtained by the methods just described. We had some similar results in patients treated by the Roger Anderson method. This apparatus permits only about 30 degrees' flexion during its use because the lower pins impinge on the vastus externus muscle, but this 30 degrees gives a good amount of activity and the amount quickly moves up once the pins are removed. It permits the patient to be up and about, with great advantage to his general condition. There is a great misunderstanding as to the time of healing of these fractures. The average is twelve to fifteen weeks, not eight. In eighteen years I have seen only one adult whose fracture healed solidly in eight weeks. Immobilization for this prolonged time of course makes the knee the problem that it is. Careful use of skeletal traction with motion by means of a Pierson attachment is an equally valid method of combating stiffness. There is evidence, however, suggesting that skeletal traction may be the cause of an increase in the percentage of delayed unions, while traction through the knee joint is thought by many to be an influence favoring stiffness.

Too many patients on weight bearing are left to the device of walking to bring about increase of knee motion. Analysis of the gait shows that knee flexion is

purely a passive accident, incident to momentary lagging of the foot on the ground as the body weight is carried forward on the opposite leg. To flex the knee actively, the hamstrings must be used with the femur fixed to prevent hip flexion. This can be accomplished only by lying on the face and raising the foot off the table by active use of the hamstrings. The other method is that of walking backward.

Then, there is the problem of the unstable knee, due either to tear of lateral ligaments or to generalized muscular weakness of the leg. Both accomplish the same result by somewhat different mechanisms. Watson Jones demonstrated a number of such knees before and after rehabilitation treatment and stated that he had for some time given up surgical repair of the ligaments of the knee in favor of muscle training because he had found that under such treatment the knees all became functionally stable.

In conclusion I would say that a brief six months' experience with war injuries in England has greatly sharpened an interest in rehabilitation which was already fairly keen. As one grows older in orthopedic surgery the lag of function after skeletal repair makes a more and more serious impression. It would seem that our methods of securing purely physical repair have become so varied and adequate that our greatest concern should now lie in securing quicker and better return of function, for it is by function that men live.